36 SB CONSULTING

Chichica Footbridge Project

iDesign Final Report
Summer & Fall 2011

Authors:
Michael Rood
Deanna Larson
Haobo Ma
Yingying Jin
Stephanie Watts-Garcia

Advisors:
Micheal Drewyor, P.E.
Dr. Dave Watkins

MichiganTech
Create the Future

iDesign Final Report: Chichica Footbridge

Submitted By:
Michael Rood
Deanna Larson
Haobo Ma
Yingying Jin
Stephanie Watts-Garcia

Submitted To:
Michael Drewyor, P.E.
Dr. Dave Watkins

December 9, 2011

Michigan Technological University
Civil and Environmental Engineering Department
1400 Townsend Drive
Houghton, MI 49931

Disclaimer

The following footbridge design project was completed by undergraduate students in the Civil and Environmental Engineering Department of Michigan Technological University. The students worked under the supervision of faculty members but, the contents of this report should not be considered professional engineering.

***DO NOT CONSTRUCT THIS FOOTBRIDGE UNLESS PLANS HAVE BEEN APPROVED BY A PROFESSIONAL ENGINEER**

Table of Contents

List of Appendices

List of Tables

List of Figures

1.0 Executive Summary

In August 2011, the team traveled to Panama as part of the International Senior Design program at Michigan Technological University. 36 SB (switchback) Consulting was formed while collecting data for the potential footbridge and is named after experiences while in Panama. The following report presents the background and assessment of the potential bridge site as well as the footbridge design that was completed in the fall of 2011.

On the assessment trip, the team actively engaged with the communities of Tijera and Chichica. The local people want a way to cross the Quebrada Tinta River in order to safely commute between Chichica and Tijera year-round. Interviews with members of the communities were performed with the help of a Peace Corps volunteer in order to clearly understand the background and need for a footbridge. Based on this information, the necessary data for designing a footbridge was collected during the assessment trip.

The current design is a suspension type footbridge that spans the river near the existing crossing between Chichica and Tijera. Components consist of concrete foundations and anchorages, steel cables, steel towers, and a steel/timber walkway. The decisions for this design were based on the communities' desires and the feasibility of such a design.

The team will be submitting this design to the Peace Corps volunteer living in Chichica as well as collaborating with Bridges to Prosperity in an effort to move forward with the construction of the footbridge. 36 SB Consulting intends to fulfill the needs of the communities by providing a sustainable and affordable footbridge design that can be constructed by the people of Chichica and Tijera.

2.0 Introduction

36 SB consulting is comprised of Yingying Jin, Deanna Larson, Haobo Ma, Michael Rood, and Stephanie Watts-Garcia, all of which are Civil Engineering undergraduates at Michigan Technological University (MTU). The team is part of the International Senior Design Program at MTU. During August 2011, the team traveled to the country of Panama and visited a community in rural Western Panama to assess a possible footbridge site location.

Panama is divided into nine provinces with three additional land areas outside these provinces called comarcas or regions. These three comarcas, known as the Kuna, Emberá, and Ngöbe Buglé, are home to the indigenous peoples of Panama. The footbridge project is located in the comarca Ngöbe Buglé where the indigenous people are part of the Ngöbe Buglé indigenous group. The footbridge would help the Ngöbe Buglé people in the Tijera community which is near the town of Chichica.

3.0 Project Description

Tijera is a community of indigenous Ngöbe people in the comarca Ngöbe Buglé in the country of Panama. **Figure 1** shows where Tijera is in relationship to the rest of Panama. Between 600 and 800 Ngöbe people live in Tijera. The nearest town to the Tijera community is Chichica, which is about a one and a half hour hike away. The two communities are separated by a river. During the months of higher precipitation, the river crossing becomes impassable as the river rises. Residents of Tijera have to travel to Chichica on a regular basis. There is a school in the Tijera community, but the education level only reaches grade six. If a student wishes to continue their education past grade six they have to travel to Chichica where education through grade twelve is offered. Chichica also has government offices that residents of Tijera need to visit.

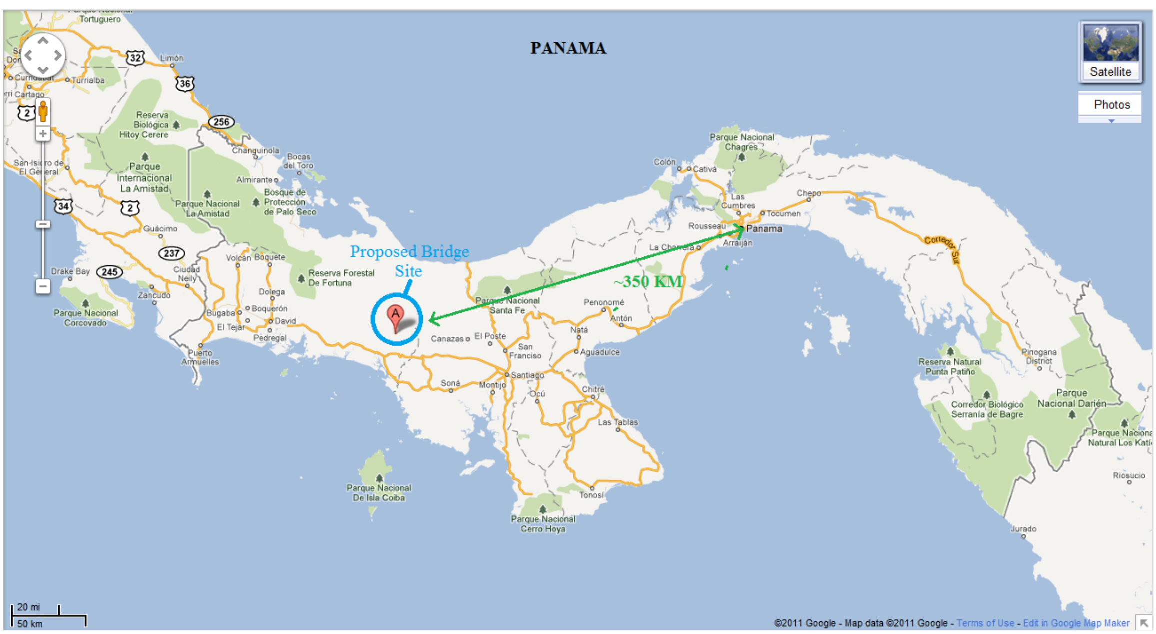


Figure 1: Map of Panama with Project Location

The trail between the Tijera community and Chichica is the shortest and most direct route; it crosses a stream named Quebrada Tinta. **Figure 2** shows a map of the Tijera community including the trail that goes from Tijera to Chichica. The water level in the Quebrada Tinta fluctuates often. According to the local Ngöbe people, the water level in the river is at its highest in the beginning and the end of the rainy season (May and November). A footbridge is needed to be able to cross the Quebrada Tinta safely year round, but especially when the water levels are extremely high.

Figure 2: Map of the Tijera Community Area

4.0 Methods and Procedures

Several tasks were done while in Panama to obtain all of the information necessary to design a footbridge. First, a feasibility survey was done in order to see where the bridge should be located and to gather information about the surrounding area. Then land surveying, soil tests, geological surveying, and water flow analysis were completed. Below are the methods used for each of these tasks.

4.1 Feasibility Survey

A feasibility survey was performed by having conversations with the local Ngöbe people about the river, the local area, and the possibility of constructing a footbridge. There were five Ngöbe men who spoke Spanish that were able to be interviewed. All of these men were asked the same questions to get the best representation of the actual answers or data. The information obtained through the feasibility survey is used throughout this report.

4.2 Surveying

The land surveying methods of the selected bridge site were measured by using tacheometry, otherwise known as stadia measurement, with the aid of a handheld GPS to obtain approximate coordinates and elevations. The equipment included: a theodolite with an optical plummet, a tripod, a level rod, a steel tape, and a compass. All calculations and procedures were performed according to *Chapters 8 and 12* from *Elementary Surveying* and *Volume B of Survey, Design and Construction of Trail Suspension Bridges for Remotes Areas*.

The bridge axis was selected based on a preliminary assessment of geologic features, accounts of high water levels, and the feasibility survey. Once the bridge axis was located, survey points for the bridge axis were placed in their appropriate location (see **Appendix A)**. Benchmarks were then placed to be inter-visible of each other and near the bridge axis points in order for the bridge structure to eventually be staked out for construction. Benchmarks were witnessed by measuring the horizontal distance and compass azimuth from the point to the face of trees. These trees were blazed with a machete on the side of the tree facing the benchmark point. The handheld GPS unit was then used to record the approximate coordinates and elevations of the benchmarks.

The topographic survey involved collecting data related to the geological, hydrological, and land use features of the bridge site. In addition, a traverse around the benchmarks and bridge axis points, shown in **Appendix A**, was performed to ensure their positions and relationships to one another were within tolerances. The measurement information of the topographic survey was recorded in addition to naming the features that were being recorded. Points of interest that were noted are accounts of the highest water level, dramatic changes in grade, larger trees close to the bridge axis, land use features, and river bed characteristics. Several photographs were also taken due to the dense foliage and changing river grades of the area to aid in the generation of a detailed topographical map. Please refer to **Appendix J, Drawing No. 1**, to see the general topographical features of the bridge site.

4.3 Soil Classification and Geological Survey

The type of soil near the bridge site needed to be identified and classified so that the bearing capacity of the soil could be estimated and used when designing the foundations and anchorages of the bridge. At each of the planned bridge foundation sites a 2 ft. x 2 ft. x 4 ft. soil test pit was dug. The soil from the test pits was separated into four layers. Each vertical foot was a layer that would get analyzed. Tests were performed according to *ASTM D 2488, Standard Practice for Description and Identification of Soils (Visual – Manual Procedure*), for color and major constituent identifications, dry strength test, dilatancy test, plasticity/ toughness test, and moisture identification on each layer. Pictures were also taken of every layer. The results can be found in **Appendix B.**

A preliminary sketch of the area surrounding the river was drawn while at the bridge site. The sketch provides a rough idea of the landscape features of the river area that helped when generating a detailed topographic map. The resulting sketch can be found in **Appendix B**.

4.4 River Flow

The hydrological survey of the Quebrada Tinta near the bridge site was completed using practical engineering methods. A sealed empty bottle was sent downstream at various sections along the river and the time and distance the bottle traveled was recorded. The method named ‘float measurement’ was defined as the distance the bottle traveled versus time. The river was divided into five sections across the river shown in **Appendix C**. There were two upstream, two downstream, and one at the approximate bridge crossing. The lines that make up a section were perpendicular to the flow of the river. The lines separating the sections were paced off to be approximately twenty feet apart. The results from the float measurements can be seen in **Appendix C**. The depth of flow was measured using a tape at the various sections along the width of the river. The river bottom is very rocky as it can be seen in **Figures 3 and 4,** both upstream and downstream of the bridge site. The width of the river was also measured using a cloth tape at the various sections along the river. The average river velocity was 1.5 ft. per second with an average flow rate of 45 cubic ft. per second. These results can be seen in **Appendix C, Table 3**.

Figure 3: Upstream River Bottom

Figure 4: Downstream River Bottom

5.0 Analysis and Design Options

5.1 Surveying

The land surveying data was input into Carlson® software with AutoCAD®. In order to ensure that the field work was performed adequately, the traverse data was processed to determine the closure precision. The raw traverse data closure precision was 1 in 902, as listed in **Appendix A**. According to *Chapter 12-12* on *Stadia Precision* in the *Elementary Surveying* text, 1 in 500 is adequate closure precision. The unadjusted traverse data that was processed is acceptable. Once this was determined, the remaining topographic data was input into the software to generate a detailed topographic map of the area. This can be seen in **Appendix J, Drawing No. 1**.

5.2 Bridge Site Hydrology

A bridge site (ungaged) hydrologic analysis had to be performed in order to establish a high water level in the Quebrada Tinta. The hydrologic analysis was completed by referring to the *World Catalogue of Maximum Observed Floods*. The catalogue has maximum flood information related to a large watershed that includes the area surrounding David, Panama. The characteristics of the larger watershed were compared to the proposed bridge site watershed. The two watersheds share the following characteristics: located in Western Panama, mountainous terrain, average to less permeable soil, and comparable land use. Based on these comparisons, use of the catalogue's values is deemed acceptable. **Table 2** shows these comparisons in more detail.

Table 1: Watershed Comparison

Location	**David, Panama**	**Bridge-Site (Chichica, Panama)**
Area (sq. miles)	463.32	2.05
Terrain slopes (percent)	> 5%	8%
Soil Permeability	average to low	average to low
Land Use	70% cultivated land 30% dense forest	60% cultivated land 30% dense forest

Since the two watersheds differ greatly in size, scaling of the rainfall intensity is required. For the bridge site watershed, if a 100-year rainfall event were to occur, it would likely completely cover the watershed area uniformly for the duration of the event. For the larger watershed surrounding David, a 100-year rainfall event would not cover the entire watershed uniformly for the duration of the event. So, based on the differences in area, a ratio multiplier was determined in order to obtain an appropriate estimate of the flood level at the bridge site. The calculated flood height for a 100-year rainfall event was compared to the local inhabitants' observations, which can be seen in **Appendix D**. The results of these calculations are lower than the flood levels observed by the local residents of Chichica and Tijera; therefore, the observed flood level was used to determine the bridge walkway elevation.

5.3 Soil Classification and Geological Survey

In **Appendix B**, it can be seen that the soils from both sides are very similar. The soil has been classified as silty-clay. The biggest difference between two test pits is that the amount of gravel in the south side pit increased with depth. During the rainy season, the moisture content is very high because of the daily rain. There were also roots and leaves in the soil. According to the local residents if a deep enough hole near where foundations are located, approximately 15 ft. deep on either bank, was dug, bed rock would be hit. The worst case soil characteristics were used when designing the anchorages and foundations to ensure a safe design.

5.4 Erosion Inspection

The banks and river bottom have favorable erosion characteristics. The river bottom is mostly bed rock and the river banks have dense foliage on either side. The roots of the trees serve as natural erosion protection. The local inhabitants pointed out where erosion takes place near the bridge site during the flooding season. Upstream of where the bridge axis was located the slopes are mainly soil with few trees, when river levels are high this area is most affected with erosion. The bridge axis is located where little to no erosion occurs during the rainy season because of trees and rocks located on the banks that serve as natural erosion protection and this was considered in design recommendations for the footbridge.

5.5 Concerns

Transportation of materials is a major part of the construction of the footbridge. The material will have to be transported by foot or by horse to the bridge site over rough and mountainous terrain, this will consume precious time during a construction window of six months during the dry season.

An experienced project manager will need to be present for key parts of the construction of the bridge. The project manager must be skilled in general engineering knowledge and most importantly, have been involved in prior bridge erection projects in similar conditions. Things such as hoisting and tensioning of the cables need to be supervised to make sure that they are executed properly.

5.6 Feasible Design Options

The landscape of the area lends to the possibility for implementing either a suspended or suspension type bridge design. The span length of a suspended bridge would be much longer than a suspension bridge and could only offer a walkway height above the highest predicted water level comparable to a suspension bridge. The footbridge needs to be as inexpensive as possible. A suspension type bridge offers the best solution. The communities are familiar with footbridges around the area and know that the ones made with lots of timber components do not last in the harsh, humid conditions. The members of the community interviewed prefer that portions of the footbridge be made out of steel because a nearby bridge has lasted for several years with little maintenance. The team visited this bridge, shown below in **Figure 5.**

Figure 5: Example Suspension Bridge in the Surrounding Area

Structural components made out of steel would make the bridge last for years and reduce the maintenance required. Again we had to take transportation into consideration. Nearly all of the materials needed to build the footbridge have to be able to be easily transported to the site. The skill of the local residents also has to be taken into consideration. The construction of the bridge is going to be completed by them, so ensuring construction can be performed is important.

6.0 Final Recommendation and Conclusion

6.1 Design Recommendations

The calculations for component design of the suspension footbridge were completed based on *Survey, Design, and Construction of Trail Suspension Bridges for Remote Areas*, and this text also includes standard design drawings. The corresponding design drawings were used once calculations were completed. The footbridge is designed for a walkway loading of 104 lbs. /sq. ft., which includes both dead and live loads. A visual representation of how many people it takes to produce a loading of 100 lbs. /sq. ft. is shown below in **Figure 6**.

Figure 6: Example of 100 psf Loading

The footbridge span is 186 feet, and was used in the *Survey, Design, and Construction of Trail Suspension Bridges for Remote Areas* to determine cable and tower conditions. The layout of the footbridge is shown below in **Figure 7** and the detailed drawing can be seen in **Appendix J, Drawing No. 2.**

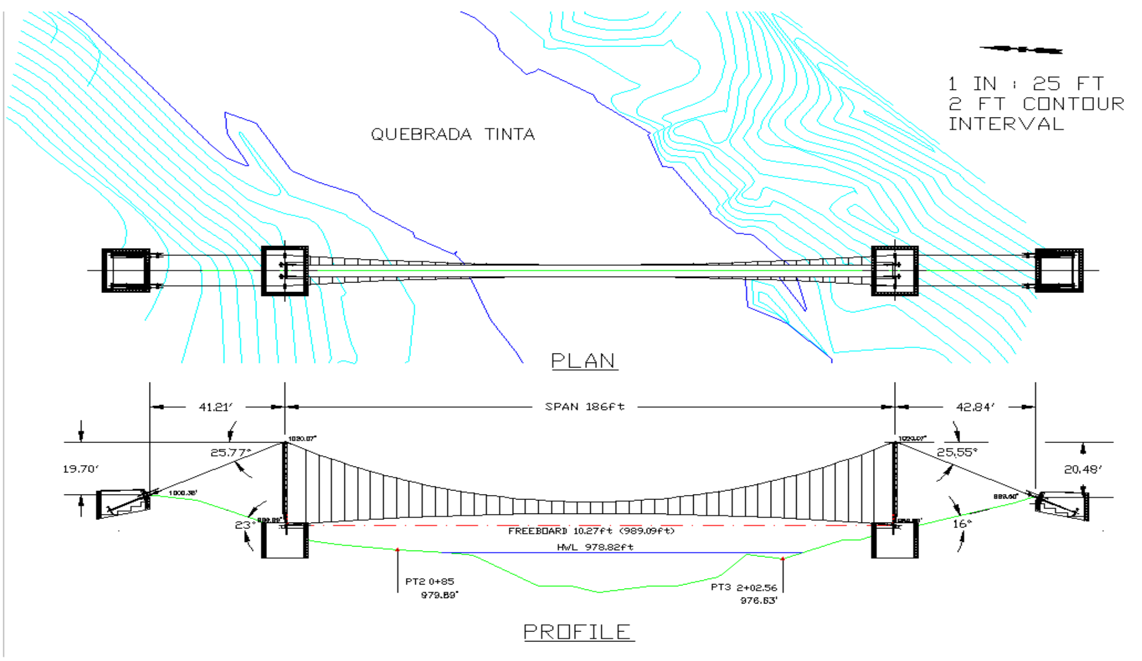


Figure 7: Snapshot of Footbridge Layout

The footbridge is skewed from being perpendicular to the river and the span is farther up the banks from the high water level. The combination of these two items take advantage of the natural erosion protection on either bank mentioned previously. This eliminates the need for extensive erosion protection and reduces maintenance around foundations.

6.1.1 Cable Design

Cables were designed to withstand dead and live loads. The main cables will consist of two, 1 3/8 inch (36 mm) diameter main suspension cable, and two, 1 inch (26 mm) diameter spanning cable. The cable calculations can be seen in **Appendix E**. The selected cables provide a safety factor of 3 to 1 in relation to the full load tension they may experience in place at the bridge site compared to the minimum breaking strength of the wire rope. The dead and hoisting load sag is also noted in **Appendix E**, and this will be referred to when the construction of the bridge is taking place. The hoisting and dead load sag elevations at the midpoint of the span will be a check to ensure the main cable is tensioned correctly.

6.1.2 Tower Design

The tower height was determined based on the span of the footbridge. The tower withstands the full vertical load from the main cables. It was checked as to whether the tower will buckle under this load. Wind loading was also placed on the tower as an additional check. The tower calculations can be seen in **Appendix F.** The tower is going to be made out of steel components which could be fabricated and welded at a fabrication shop in Santiago, Panama. The fabricated pieces will only have to be bolted together at the bridge site. To build the tower, drawings can be seen in **Appendix J, Drawing No.4**.

6.1.3 Foundation Design

The foundations were sized based on the loadings from the tower weight, the vertical loading from the cable resting on the top of the tower, and the bridge site soil characteristics. The foundation had to be sized to satisfy safety factors against sliding and bearing capacity. The foundation calculations can be seen in **Appendix G.** An additional check related to the settlement of the foundations was determined, this can be seen in **Appendix G**. The settlement and time rate of settlement checks were performed to see if, during the construction period, any portions of the project needed to be postponed due to settlement of the foundations. The settlement estimates are minimal and will not affect the construction process in a significant way.

The foundations will consist of a masonry block exterior that will be filled with concrete. Additional steel components will be put in place to fasten the towers and walkway to the foundation, these will also require fabrication. Reinforcement and hooks will also be placed in the concrete. The hooks will be used to assist in tower erection and cable hoisting. The detailed design drawings can be seen in **Appendix J, Drawing No. 5**.

6.1.4 Anchorage Design

Main cable anchorage blocks were sized using the same soil characteristics for foundation design and also satisfied the same safety factors for sliding and bearing capacity. The calculations performed to size the anchorage blocks can be seen in **Appendix H**. The anchorage blocks were placed at certain backstay distances from the towers to ensure that the angles of elevation for the main cables on either side of the top of the tower were approximately the same. Since the settlement of the larger foundation blocks was minimal, a settlement check related to the anchorages was not performed.

The anchorages will be formed and filled with concrete. Similar to the foundations, steel components and hooks will be placed in the anchorage blocks for the attachment of the main cables. The hooks will be used to assist in tower erection and main cable tensioning. The detailed design drawings can be seen in **Appendix J, Drawing No. 5**.

6.1.5 Suspender and Walkway Design

The suspenders are going to be made of 1/2 in. (12mm) diameter rods. They were designed to withstand the loadings from the walkway and live loads. The suspender calculations can be seen in **Appendix I**. The suspenders were sized to fit between the main and spanning cables, according to the dead load sag of the main cables and the dead load camber of the spanning cables. Detailed design drawings for the suspenders can be seen in **Appendix J, Drawing No. 3**. The suspenders will require fabrication and welding. and will then be bolted in place during construction.

The walkway is going to be made of steel frame parts with a wood decking. The wood that is available locally and going to be used as the decking is similar to Southern Pine. Checks were performed on the timber to make sure that it could withstand the worst case loadings. The three checks that were performed, according to NDS-05, *National Design Specification for Wood Construction*, are bending, shear, and deflection. The size and characteristics of the timber were used to complete these checks. Southern Pine timber passed all of these checks, as can be seen in **Appendix G**, and therefore the wood available is adequate to use as our decking. A detailed drawing of the walkway can be seen in **Appendix J, Drawing No. 5-10**.

6.2 Construction

The construction schedule was completed using general construction knowledge while closely referencing *RS Means Building Construction Cost Data*, the Bridges to Prosperity construction manual, *Volume 1: Guidelines for Survey, Design & Construction*, and *Volume D: Execution of Construction Works* of *Survey, Design and Construction of Trail Suspension Bridges for Remote Area.* From these a realistic schedule for construction of a bridge in a rural setting was developed.

The footbridge is expected to take 20 weeks to construct. This includes the time needed to transport all materials. An additional year was added to the construction schedule to account for the mobilization needed for the project. The construction schedule can be seen in **Appendix L** with the detailed description of individual tasks. A selection of Bridges to Prosperity manual pages is also attached to assist with the construction of the footbridge. This is shown in **Appendix M**. Since the bridge requires several items to be fabricated, shop drawings from the standard design drawing volumes of *Survey, Design and Construction of Trail Suspension Bridges for Remote Areas* have been compiled into **Appendix K**. These can be used to assist in the fabrication process of the steel components.

6.3 Cost Estimate

Table 2: Overall Cost Estimate

Overall Estimate		
Item	**Total Cost**	**Actual Cost (Donations Subtracted)**
Materials	$40,500	$35,500
Labor	$22,000	$3000
Equipment	$4500	$4500
Total	**$67,000**	**$43,000**

The footbridge is estimated to cost a total of $43,000, as shown above in **Table 1**. For a complete breakdown of the cost estimate, refer to **Appendix N**. The cost estimate was completed by using a number of references for prices of materials, equipment, and transportation needed for the construction of the footbridge. First, a list of materials that can be bought close to Chichica (in Tolé), such as rebar and cement, was obtained. The Peace Corps Volunteers in the area, Jessica Rudder and Chris Kingsley provided prices for these items. A store, Cochez®, was found via the internet in Santiago, which is a construction material distributor. This store is the closest one to Chichica that has the materials not available in Tolé. A sales representative with Cochez® provided the prices for these additional materials. The steel required for the foundations, anchorages, towers, and suspenders will be fabricated in Santiago. The price of steel was based on the weight of the steel and also the number of cuts and drills and amount of paint needed for all of the pieces. Prices were obtained for the cable and cable accessories through a Bridges to Prosperity corporate partner, Heco Slings Inc. Robin Long, the Director of Operations for Bridges to Prosperity, confirmed that the cable can be donated, but the cable accessories will have to be paid for.

A majority of equipment prices for simple tools were also obtained from speaking with the sales representative with Cochez®. Rental prices of other items were obtained from two companies, Airco Inc. and Madina Tools Rental Inc., both located in David. A significant amount of the fabrication will be done in Santiago which will require less power tools/equipment at the bridge site.

Cochez® also offers delivery from Santiago to Tolé and they provided transportation costs per trip between the two locations. Both Airco Inc. and Madina Tools Rental Inc. also deliver equipment and a price was provided to transport the equipment from David to Tolé. It was determined that chivas' could be rented to transport the materials to Chichica from Tolé. Jessica Rudder provided the cost to rent a chiva for one day. Even though the cable is going to be donated, the cost of transportation from Norfolk, Virginia to the bridge site had to be determined. A shipping rate was found from Norfolk, Virginia to Panama City, along with a rate to transport the cable from the port in Panama City to Tolé to estimate the total cost to transport the cable and cable accessories.

Research was done to find the average cost of a project manager and a construction laborer in Panama. *RS Means Building Construction Cost Data* was used to estimate how long tasks would take. These two things combined were used to estimate the total labor cost to construct the bridge.

6.4 Future Recommendation and Conclusion

Upon completing the design of the footbridge near the communities of Chichica and Tijera, the next steps to implement the design would be a partnership between the Peace Corp Volunteer Jessica Rudder, Bridges to Prosperity or a similar non-governmental organization, and the community members. An experienced project manager located in Panama will also need to be sought out if the project were to move forward. The design itself will require some reviewing by a professional engineer to ensure that all aspects of the project are safe and feasible. The project design was completed with the intention of creating a sustainable yet inexpensive footbridge.

7.0 Acknowledgements

ISD Advisors:

Dr. David Watkins

Michael T. Drewyor, P.E

Peace Corps volunteers:

Jessica Rudder

Chris Kingsley

Others:

Robin Long, Director of Operations, Bridges to Prosperity

Dr. Stanley J. Vitton

8.0 References

Acosta, Caeitano. Personal interview. 12 August 2011.

ASTM Standard D2488-09a, 2009, "Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)," ASTM International, West Conshohocken, PA, 2009, DOI: 10.1520/D2488-09A , www.astm.org.

Blanco, Chido. Personal interview. 11 August 2011.

Bridge Manuals, Helvetas Bridge Manuals, Short Span Trail Bridge Standard Suspension Type, Technical Handbook. Web. 30 Sept. 2011. http://www.bridgestoprosperity.org/Resources/bridge-manuals/bridge-manuals.htm.

Brinker, Russell Charles. *Elementary Surveying: 5th Ed.* Scranton,Pa: International Textbook Co., 1969.

Camarena, Maceros. Personal interview. 12-13 August 2011.

Coduto, Donald P., Man-chu Ronald Yeung, and William A. Kitch. Geotechnical Engineering Principles and Practices. New Delhi: PHI Learning, 2010. Print.

Google Maps. Web. 15 Sept. 2011. http://maps.google.com/maps?hl=en.

Kingsley, Chris. Personal interview. 10-16 August 2011.

Krahenbuhl, J., Wagner, A. Survey, Design and Construction of Trail Suspension Bridges for Remote Areas. B. Gallen, Switzerland: SKAT, 1983. Print.

LRFD Guide Specifications for Design of Pedestrian Bridges, American Association of State Highway and Transportation Officials, Washington, DC.

2005 National Design Specification (NDS) for Wood Construction. American Forest & Paper Association: American Wood Council,2005.Washington, D.C.

"Panama." *Wikipedia, the Free Encyclopedia*. Web. 15 Nov. 2011. http://en.wikipedia.org/wiki/Panama.

Rudder, Jessica. Personal interview. 10-16 August 2011.

Wurbs, Ralph A., and Wesley P. James. *Water Resources Engineering*. 1st. Upper Saddle River: Prentice Hall, 2002. 76-77. Print.

APPENDIX A: LAND SURVEYING DESCRIPTIONS AND RESULTS

List Points Report

PointNo.	Northing(Y)	Easting(X)	Elev(Z)	Description
1	5018.63	4935.02	993.85	North Ridge
2	5051.27	4972.65	994.94	North Ridge
3	5066.63	5033.79	998.63	North Ridge
4	5056.52	5039.18	993.06	Down N Ridge
5	5046.73	5047.77	984.81	N Trail
6	5054.47	5082.67	980.23	N Trail
7	5023.27	5024.68	982.33	N Trail
8	5021.72	5001.37	983.19	N Trail
9	5018.54	4970.78	985.24	N Trail
10	5008.38	4952.23	987.02	N Trail
11	4970.10	4955.04	979.67	N Bank
12	4983.94	4984.97	979.67	N Bank
13	5006.09	5023.21	980.44	N Bank
14	5023.00	5051.05	980.86	N Bank
15	5001.52	5045.96	978.82	HWL
16	4988.10	5040.25	978.34	Edge N Bank
17	4968.72	5023.05	976.60	Edge N Bank
18	4979.74	5012.81	978.81	N Bank
19	4955.11	4998.95	977.07	N Bank
20	5071.00	5108.68	973.01	NE River Edge
21	5047.38	5145.33	973.50	SE River Edge
22	5039.64	5120.39	971.99	Center River
23	5035.52	5110.14	972.04	Center River
24	5006.19	5119.77	975.78	S Rocky Shore
25	5007.23	5136.78	977.29	Edge S Rocky
26	5002.39	5088.94	977.59	Edge S Rocky
27	5002.80	5081.46	971.05	Center River
28	4976.86	5087.71	972.78	S Edge River
29	4966.83	5112.20	978.94	Fence Line
30	4964.04	5134.26	981.86	S Trail
31	4946.89	5100.87	978.77	Top Edge River
32	4956.04	5085.80	969.30	Corner Inlet
33	4957.32	5068.97	967.95	River Bottom
34	4942.66	5055.76	967.19	S River Edge
35	4926.18	5044.19	967.07	S River Edge
36	4908.60	5026.29	966.97	S River Edge
37	4906.80	5018.82	966.78	S River Edge
38	4911.28	5057.93	977.07	S Edge Bank
39	4913.86	5071.58	980.33	S Hillside
40	4902.39	5067.96	983.84	S Hillside
41	4932.03	4959.77	978.37	N Bank
42	4964.00	5023.46	975.51	N Bank
43	4957.25	5028.17	970.36	Rock Edge
44	4952.36	5028.99	966.00	N Edge River
45	4944.11	5036.93	964.10	Center River
46	4937.31	5044.65	963.87	S Edge River
47	4911.53	5028.13	965.18	S Edge River
48	4915.41	5009.17	964.17	Center River

PointNo.	Northing(Y)	Easting(X)	Elev(Z)	Description
49	4917.38	4999.46	965.13	N Edge River
50	4917.74	4989.58	969.96	N Bank Edge
51	4936.29	4993.89	972.81	N Bank Edge
52	4930.78	5020.82	965.08	Base 60" Tree
53	4963.77	5036.57	966.55	N Edge River
54	4981.12	5051.12	968.54	N Edge River
55	4950.97	5043.90	966.59	S Edge River
56	4949.68	5047.71	962.25	Center River
57	4941.90	5053.45	965.64	S Edge River
58	4964.47	5067.29	966.70	Center Inlet
59	4965.57	5061.72	969.11	Center River
60	4977.47	5051.75	975.49	N Edge River
61	4984.42	5051.81	968.34	N Bank Edge
62	4941.58	5141.14	994.02	SE Hillside
63	4952.66	5192.02	1008.79	SE Top Hill
64	4967.17	5187.38	1009.22	SE Top Hill
65	4927.04	5147.98	992.89	SE Hillside
66	4919.09	5162.30	993.28	SE Hillside
67	4910.76	5139.56	985.29	SE Hillside
68	4921.50	5136.04	984.33	S Trail
69	4961.34	5134.33	982.22	S Trail
70	4947.23	5101.80	978.88	E Bank Edge
71	4950.09	5099.02	971.50	E Edge Inlet
72	4926.97	5120.28	981.72	E Edge Inlet
73	4918.49	5128.40	982.62	E Edge Inlet
74	4913.05	5121.90	982.84	Center Inlet
75	4909.51	5115.67	983.04	W Edge Inlet
76	4920.30	5109.99	981.16	W Edge Inlet
77	4922.08	5092.41	985.07	Base Tree 40"
78	4906.90	5097.60	985.81	S Trail
79	4908.86	5083.83	988.19	S Trail
80	4943.39	5089.55	973.80	W Edge Inlet
81	4931.69	5086.93	976.03	S Bank
82	4926.31	5072.64	975.43	Fence Line
83	4912.41	5072.22	981.22	S Bank
84	4893.57	5090.31	995.76	S Hillside
85	4863.78	5097.70	1008.27	S Top Hillside
86	4848.25	5088.55	1008.46	S Top Hillside
87	4832.94	5076.95	1007.10	S Top Hillside
88	4818.87	5065.21	1007.15	S Top Hillside
89	4807.59	5050.64	1004.49	S Top Hillside
90	4807.39	5039.22	999.33	S Hillside
91	4815.94	5029.38	992.98	S Hillside
92	4850.78	5051.22	992.35	S Trail
93	4866.04	5061.34	992.97	S Trail
94	4888.80	5058.94	983.96	S Bank
95	4868.66	5044.29	984.33	S Bank
96	4832.81	4998.96	978.57	S Bank
97	4821.84	4985.84	978.56	S Bank
98	4892.87	5026.96	983.36	Fence Line
99	4902.99	5046.56	974.13	Fence Line

PointNo.	Northing(Y)	Easting(X)	Elev(Z)	Description
100	4916.85	5060.22	975.29	Fence Line
101	4914.14	5080.35	983.02	S Bank
102	4864.67	4976.18	966.38	S Edge River
103	4870.71	4977.65	965.14	Center River
104	4900.58	4988.90	967.91	Top Boulder
105	4987.79	5090.57	971.21	W Boulder
106	5007.20	5086.91	971.21	Rock Field
107	4995.78	5127.17	976.17	Rock Field
108	5042.01	5153.93	974.94	Rock Field
109	5102.30	5129.69	974.43	N Edge River
110	5085.66	5112.35	974.53	N Trail
111	5062.05	5081.88	975.92	N Trail
112	5039.12	5057.77	980.57	N Trail
113	4991.61	5066.14	971.57	Top River
114	4986.41	5076.40	967.97	Eddy Currents
115	4984.52	5083.68	969.18	Eddy Currents
116	5004.47	5084.30	968.05	Spillway
117	5037.37	5098.47	971.90	River Bottom
118	5082.05	5179.38	976.10	River Bottom
119	5120.41	5142.61	974.25	River Bottom
120	5127.21	5074.15	1007.90	North Ridge
121	5011.28	5013.44	980.00	Tree 14"
122	5018.94	4995.97	980.00	Tree 14"
123	5006.09	4994.51	980.00	Tree 13"
124	4975.41	4982.13	980.00	Tree 12"
125	4921.45	5089.67	989.78	Tree 40"
126	4899.17	5067.08	989.78	Tree 6"
127	4874.43	5062.25	989.78	Tree 24"
128	4867.07	5069.45	989.78	Tree 12"
200	4870.65	5005.55	979.66	Fence Line
201	4845.11	4981.04	977.17	Fence Line
202	4852.24	5025.58	981.84	S Bank
203	4873.75	5004.90	968.48	S Bank
204	4849.16	4980.91	966.84	River Bottom
BM1	5000.00	5000.00	980.00	
BM2	4895.49	5073.45	989.78	
PT2	5004.73	5033.67	979.89	
PT3	4887.26	5038.22	976.63	
PT4	4963.87	5117.49	979.38	

Number of points listed **138**

Traverse No Adjust Results

Stadia Reduction Method
Scale Factor: 1.00000000
Correct for Earth Curvature: OFF

Closure Results
Starting Point BM1: N 5000.000 E 5000.000 Z980.000
Closing Reference Point PT2: N 5004.732 E 5033.669 Z979.890
Ending Point PT2: N 5005.055 E 5033.907 Z 980.007

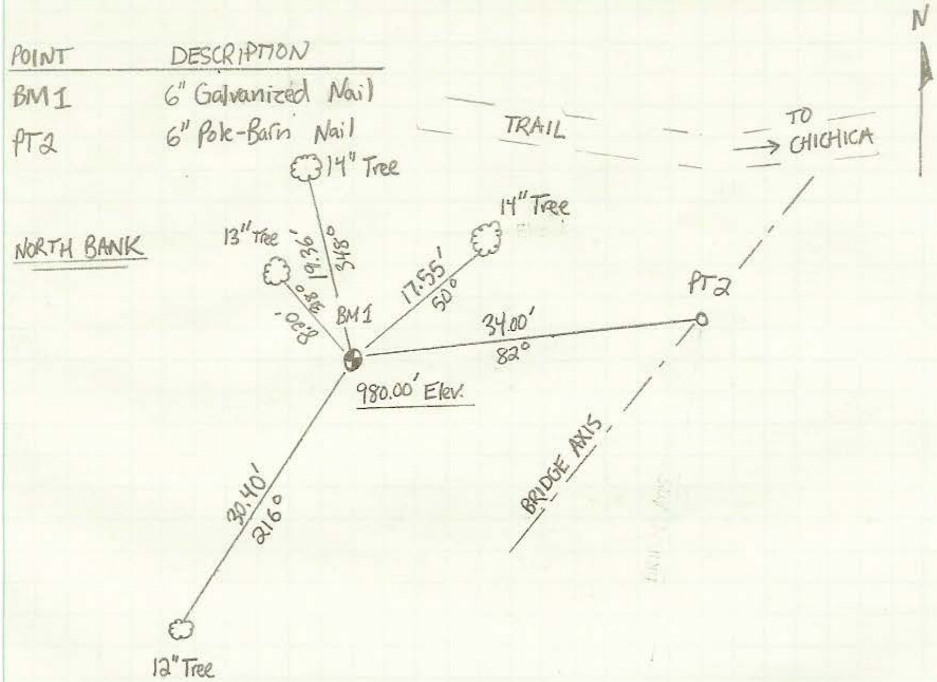
Azimuth Of Error: 36°23'31"
North Error : 0.32272
East Error : 0.23786
Vertical Error : 0.11673
Hz Dist Error : 0.40091
Sl Dist Error : 0.41756
Traverse Lines : 5
SideShots : 0
Store Points : 1
Horiz Dist Traversed: 361.720
Slope Dist Traversed: 364.731

Closure Precision: 1 in 902

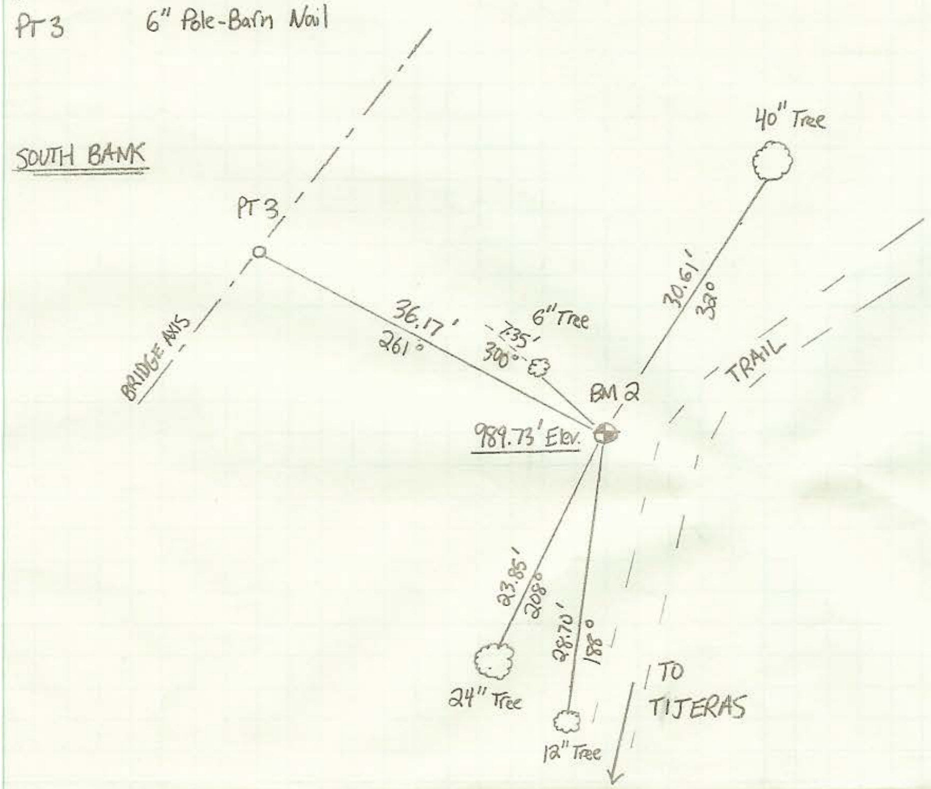
Starting Point BM1: N 5000.000 E 5000.000 Z 980.000
BackSight Azimuth: 00°00'00"

Point	Horizontal	Elev	Slope	Inst	Rod	Northing	Easting	Elev
PT2	AZ82.0000	-0.1100	34.000	0.000	0.000	5004.732	5033.669	979.890
PT4	AL146.0030	-0.5100	93.251	0.000	0.000	4963.867	5117.486	979.380
BM2	AL83.1215	10.4000	81.992	0.000	0.000	4896.046	5073.800	989.696
PT3	AL135.5615	-13.1500	38.486	0.000	0.000	4888.312	5040.698	977.337
PT2	AL80.1045	2.6700	117.000	0.000	0.000	5005.055	5033.907	980.007

POINT	DESCRIPTION
BM 1	6" Galvanized Nail
PT 2	6" Pole-Barn Nail



POINT	DESCRIPTION
BM 2	6" Galvanized Nail
PT 3	6" Pole-Barn Nail



APPENDIX B: SOIL TESTS AND SITE GEOLOGICAL SURVEY RESULTS

Visual Identification Process for Soil

1. Identify the color (e.g. brown, gray, brownish gray), odor (if any) and texture (coarse or fine-grained) of soil
2. Identify the major soils constituent (>50% by weight) using Table 1 in Lab1 handout, as coarse gravel, fine gravel, coarse sand, medium sand, fine sand or fines.
3. Estimate percentages of all other soil constituents using Table One and the following terms: trace – 0 to 10% by weight, little – 10 to 20%, some – 20 to 30%, and – 30 to 50%.
4. If the major constituent is sand or gravel: Identify particle distribution (Describe as well-graded or poorly-graded) and particle shape (angular, subangular, rounded, subrounded) using Figure One and Table 2 in Lab1 handout.
5. If the major constituents are fines, perform the following tests:
   - Dry Strength Test: Mold a sample into 1/8" size ball and let it dry. Test the strength of the dry sample by crushing it between the fingers. Describe the strength as none, low, medium, high, or very high depending on the results of the test shown in Table 3 in Lab1 handout.
   - Dilatancy Test: Make a sample of soft putty consistency in your palm. Then observe the reaction during shaking, squeezing (by closing your hand) and vigorous tapping. The reaction is rapid, slow, or none according to the test results given in Table 4.
   - Plasticity (or Toughness) Test: Roll the samples into a thread about 1/8" in diameter. Fold the thread and reroll it repeatedly until the thread crumbles at a diameter of 1/8".
     (a) The pressure required to roll the thread when it is near crumbling
     (b) Whether it can support its own weight.
     (c) Whether it can be molded back into a coherent mass.
     (d) Whether it is tough during kneading.

     Describe the plasticity and toughness according to the criteria in Tables 5 and 6 in Lab1 handout.
6. Identify moisture condition (dry, moist, wet, or saturated) using Table 8 in Lab1 handout.
7. Record visual classification of the soil in the following order: color, major constituent, minor constituent, particle distribution and particle shape (if major constituent is coarse-grained), plasticity (if major constituent is fine-grained), moisture content, soil symbol (if major constituent is fine-grained).

North Side Soil N-1

Classified By: YJ & HM Date: 8/13/11

Color	Odor	Texture	Major Soil Constituent	Minor Soil Constituents	Moisture condition	Dry Strength	Low
						Dilatancy	Fast, shiny surface
Brown	Earth, organics, musty	Fine	Fine Silt	Coarse gravel	Moist	Plasticity	Low
						Toughness	Low
						Soil Symbol	ML

Classification: brown, fines with 10% coarse gravel, and low plasticity, rounded, moist

Notes:



North Side Soil N-2

Classified By: YJ & HM Date: 8/13/11

Color	Odor	Texture	Major Soil Constituent	Minor Soil Constituents	Moisture condition	Dry Strength	Low
						Dilatancy	Fast, shiny surface
Dark brown	Earth, organics, musty	Fine	Fine silt	Coarse gravel	Moist	Plasticity	Low
						Toughness	Low
						Soil Symbol	ML

Classification: brown, fines with 5% coarse gravel, and low plasticity, rounded, moist

Notes:



North Side Soil N-3

Classified By: <u>YJ & HM</u> Date: <u>8/13/11</u>

Color	Odor	Texture	Major Soil Constituent	Minor Soil Constituents	Moisture condition	Dry Strength	Low
						Dilatancy	Fast, shiny surface
Dark brown	Earth, organics, musty	Fine	Fine silt	Coarse gravel	Moist	Plasticity	Low
						Toughness	Low
						Soil Symbol	ML

Classification: brown, fines with 2% coarse gravel, and low plasticity, rounded, moist

Notes:



North Side Soil N-4

Classified By: <u>YJ & HM</u> Date: <u>8/13/11</u>

Color	Odor	Texture	Major Soil Constituent	Minor Soil Constituents	Moisture condition	Dry Strength	None
						Dilatancy	Fast, shiny surface
Dark Brown	Earth, organics, musty	Fine	Fine silt	Coarse gravel	Moist	Plasticity	Low
						Toughness	Low
						Soil Symbol	ML

Classification: brown, fines with 1% coarse gravel, and low plasticity, rounded, moist

Notes:



South Side Soil S-1

Classified By: <u>YJ & HM</u> Date:<u>8/13/11</u>

<table>
<tr><th rowspan="2">Color</th><th rowspan="2">Odor</th><th rowspan="2">Texture</th><th rowspan="2">Major Soil Constituent</th><th rowspan="2">Minor Soil Constituents</th><th rowspan="2">Moisture condition</th><th>Dry Strength</th><td>Low</td></tr>
<tr><th>Dilatancy</th><td>Fast, shiny surface</td></tr>
<tr><td rowspan="3">Brown</td><td rowspan="3">Earth, organics, musty</td><td rowspan="3">Fine</td><td rowspan="3">Fine Silt</td><td rowspan="3">Coarse gravel</td><td rowspan="3">Moist</td><th>Plasticity</th><td>Low</td></tr>
<tr><th>Toughness</th><td>Low</td></tr>
<tr><th>Soil Symbol</th><td>ML</td></tr>
</table>

Classification: brown, fines with 5% coarse gravel, and low plasticity, rounded, moist

Notes:



South Side Soil S-2

Classified By: <u>YJ & HM</u> Date:<u>8/13/11</u>

<table>
<tr><th rowspan="2">Color</th><th rowspan="2">Odor</th><th rowspan="2">Texture</th><th rowspan="2">Major Soil Constituent</th><th rowspan="2">Minor Soil Constituents</th><th rowspan="2">Moisture condition</th><th>Dry Strength</th><td>Low</td></tr>
<tr><th>Dilatancy</th><td>Fast, shiny surface</td></tr>
<tr><td rowspan="3">Dark brown</td><td rowspan="3">Earth, organics, musty</td><td rowspan="3">Fine</td><td rowspan="3">Fine silt</td><td rowspan="3">Coarse gravel</td><td rowspan="3">Moist</td><th>Plasticity</th><td>Low</td></tr>
<tr><th>Toughness</th><td>Low</td></tr>
<tr><th>Soil Symbol</th><td>ML</td></tr>
</table>

Classification: brown, fines with 10% coarse gravel, and low plasticity, rounded, moist

Notes:

South Side Soil S-3

Classified By: <u>YJ & HM</u> Date:<u>8/13/11</u>

<table>
<tr><th rowspan="2">Color</th><th rowspan="2">Odor</th><th rowspan="2">Texture</th><th rowspan="2">Major Soil Constituent</th><th rowspan="2">Minor Soil Constituents</th><th rowspan="2">Moisture condition</th><th>Dry Strength</th><td>Low</td></tr>
<tr><th>Dilatancy</th><td>Fast, shiny surface</td></tr>
<tr><td rowspan="3">Dark brown</td><td rowspan="3">Earth, organics, musty</td><td rowspan="3">Fine</td><td rowspan="3">Fine silt</td><td rowspan="3">Coarse gravel</td><td rowspan="3">Moist</td><th>Plasticity</th><td>Low</td></tr>
<tr><th>Toughness</th><td>Low</td></tr>
<tr><th>Soil Symbol</th><td>ML</td></tr>
</table>

Classification: brown, fines with 15% coarse gravel, and low plasticity, rounded, moist
Notes:

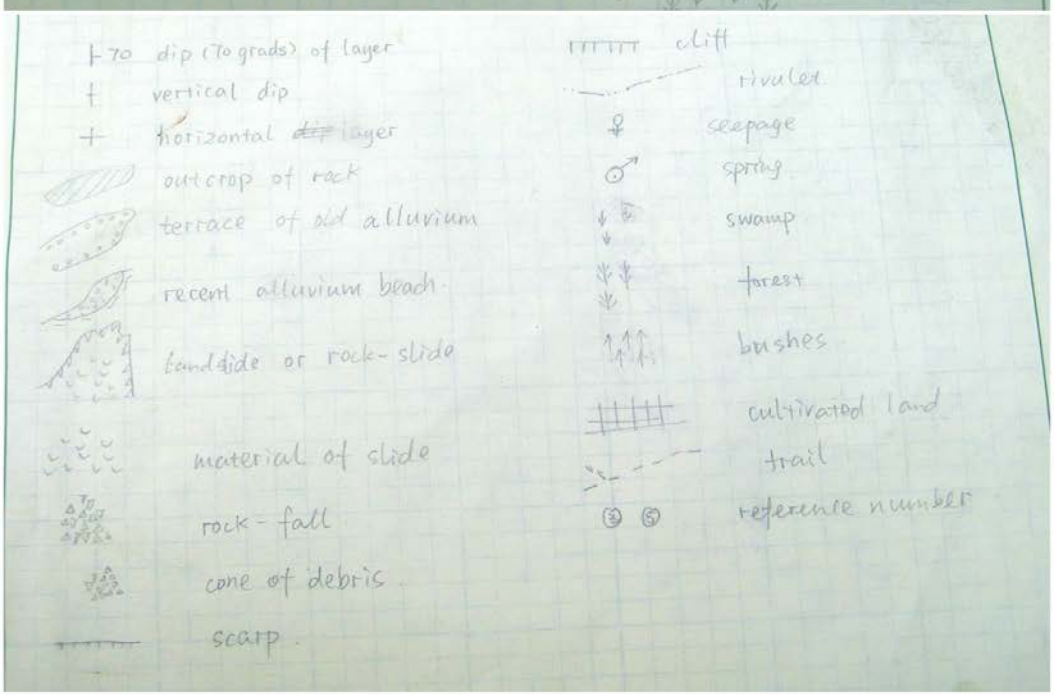
South Side Soil S-4

Classified By: YJ & HM Date:8/13/11

Color	Odor	Texture	Major Soil Constituent	Minor Soil Constituents	Moisture condition	Dry Strength	None
						Dilatancy	Fast, shiny surface
Dark Brown	Earth, organics, musty	Fine	Fine silt	Coarse gravel	Moist	Plasticity	Low
						Toughness	Low
						Soil Symbol	ML

Classification: brown, fines with 20% coarse gravel, and low plasticity, rounded, moist
Notes:

N
E
S
W
waterflow
water flow



70 dip (70 grads) of layer
vertical dip
horizontal dip layer
outcrop of rock
terrace of old alluvium
recent alluvium beach
landslide or rock-slide
material of slide
rock-fall
cone of debris
scarp
cliff
rivulet
seepage
spring
swamp
forest
bushes
cultivated land
trail
reference number

APPENDIX C: WATER FLOW ANALYSIS

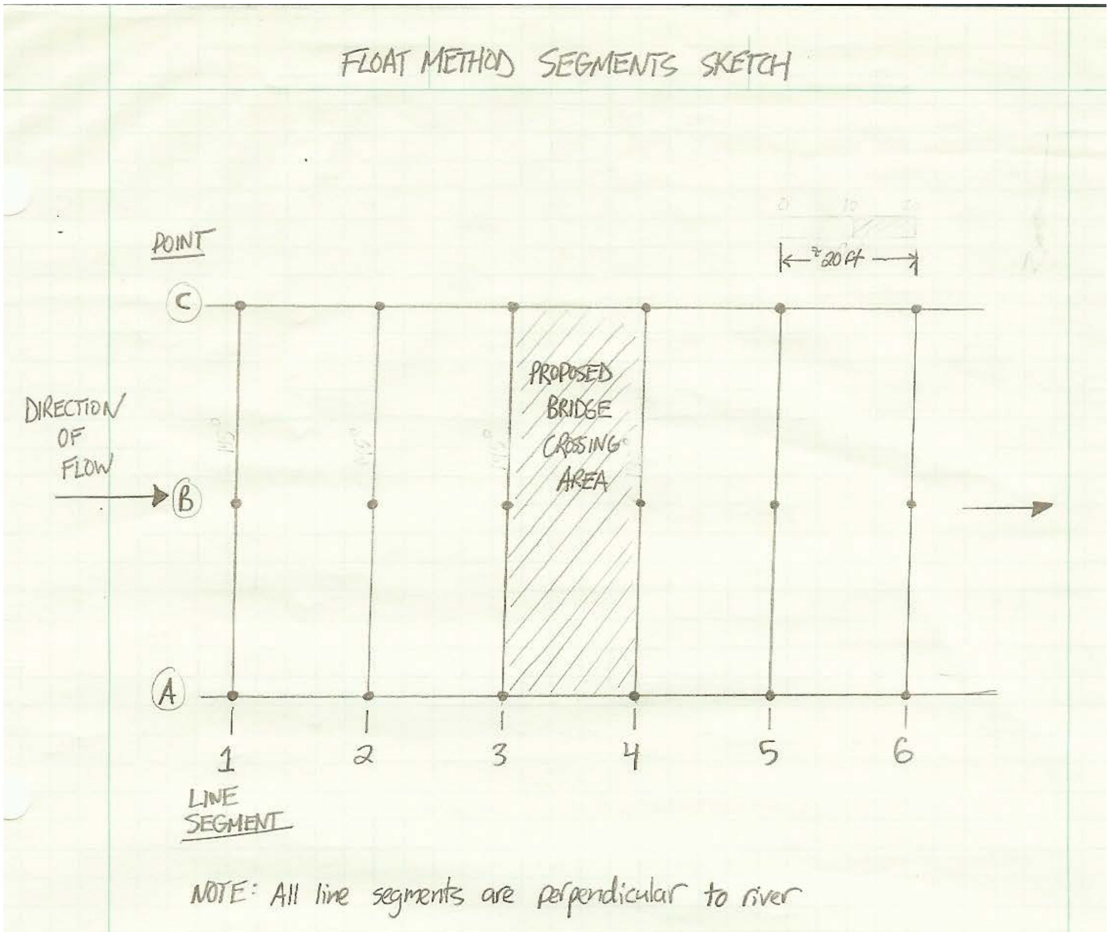


Table 1: Depth of River in Each Section

Line Segment	Depth of Flow (inches)		
	A	B	C
1	5.91	9.45	6.69
2	6.69	13.78	8.27
3	6.30	2.76	6.69
4	9.45	12.99	7.09
5	4.92	7.09	4.33
6	10.63	12.20	5.71

Table 2: Travel Time of Bottle in Each Section

Line Segment	Travel Time for Segment (seconds)		
	A	B	C
1	47.00	47.00	47.00
2	19.00	19.00	19.00
3	44.00	44.00	44.00
4	20.01	20.81	20.28
5	17.80	13.87	33.26
6	20.64	28.34	20.33

Table 3: River width in Each Section

Line Segment	River Width (feet)
1	43.20
2	46.30
3	49.70
4	50.20
5	17.20
6	37.40

Average Velocity = 1.5 ft/s

Average Flow rate = 45ft^3/s

APPENDIX D: BRIDGE SITE HYDROLOGY

Reference:

Rodier, J. A., M. Roche, and Reginald W. Herschy. World Catalogue of Maximum Observed Floods / Répertoire Mondial Des Crues Maximales Observées / Composé [i.e. Revisé] Par Reg Herschy. Wallingford, Oxfordshire: International Association of Hydrological Sciences, 1984. Print.

Reasons for Use and Comparison:

Observation Site: David, Chiriquí

- close proximity to Chichica, Comarca: Ngöbe-Bügle
- both sites are in western Panama

Characteristics of the Basin:

- relatively steep slopes, greater than 5%
- similar to our basin

Soil Characteristics:

- Low to average permeability

Land Cover:

- 30-40% dense forest
- 60-70% cultivated land

Calculating Discharge

Referring to page 163 (David, Panama); Table 2: flood characteristics

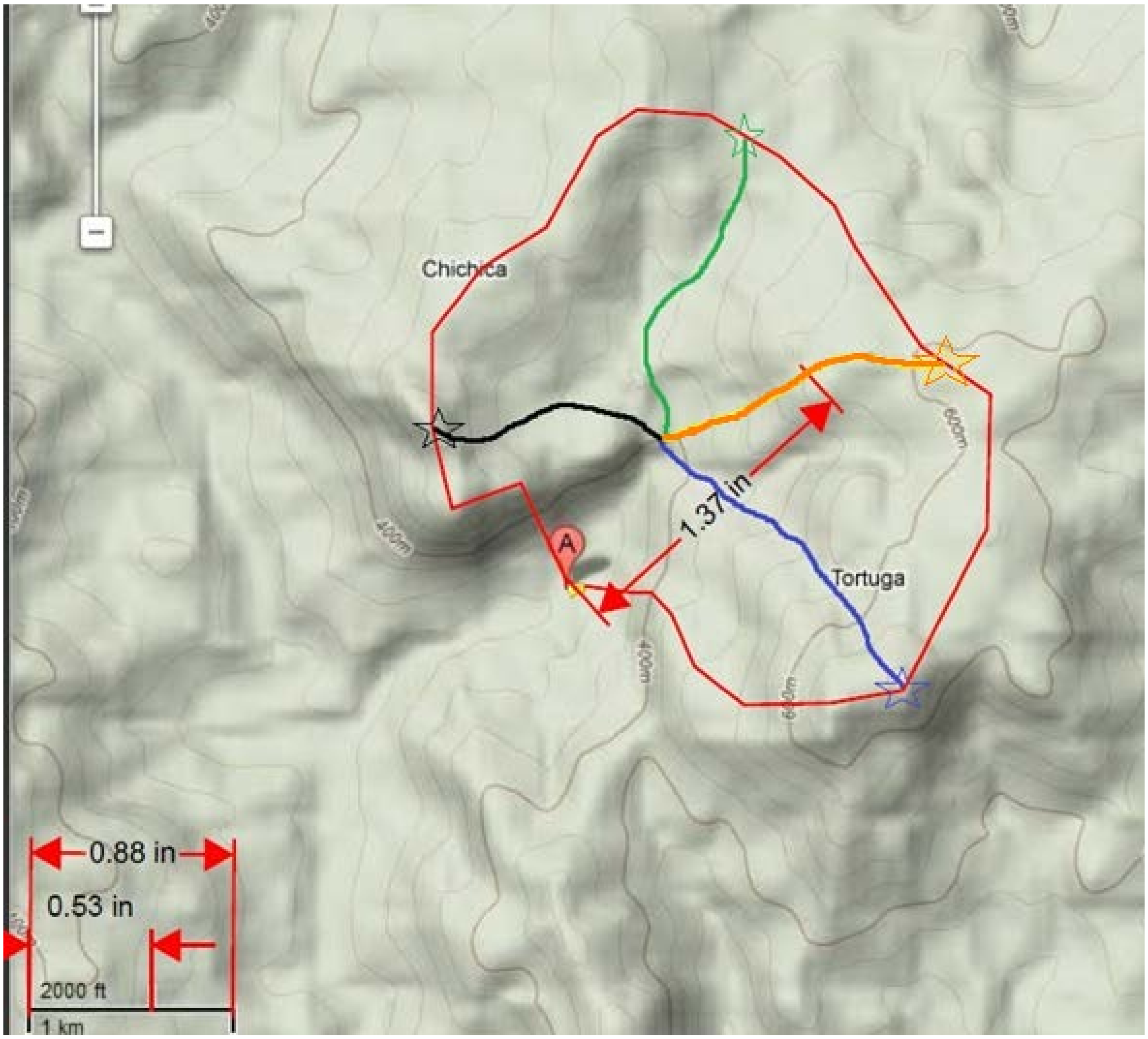
Maximum Instantaneous Flood Discharge:

- October 2nd, 1974
- 2980 cms=105,238 cfs
- For a basin area equal to 1200 km^2

$$Maximum\ Flood\ Discharge, cfs = \frac{Discharge, cfs}{Basin\ Area, km^2} * Rough\ Watershed\ Area, km^2$$

$$\frac{105{,}230\ cfs}{1200\ km^2} * 5.31\ km^2 = 465.64\ cfs$$

Calculations for Smaller Watershed



Measured Lengths* (colored lines) and Point Elevations (colored stars):

$$L_{blue} = 2.26\ in,\ \ y_{blue} = 680\ m$$

$$L_{black} = 1.65\ in,\ \ y_{black} = 580\ m$$

$$L_{green} = 2.25\ in,\ \ y_{green} = 510\ m$$

$$L_{orange} = 2.125\ in,\ \ y_{orange} = 610\ m$$

*Note: Lengths were measured with string using provided scale directly on the computer screen, not on the printed picture

Equate Lengths (in) to Lengths (ft):

Given: 0.53 in = 2,000 ft

$$2.26\ in * \left(\frac{2000\ ft}{0.53\ in}\right) = 8{,}528.3\ ft\ (L_{blue})$$

$$1.65\ in * \left(\frac{2000\ ft}{0.53\ in}\right) = 6{,}226.4\ ft\ (L_{black})$$

$$2.25\ in * \left(\frac{2000\ ft}{0.53\ in}\right) = 8{,}490.6\ ft\ (L_{green})$$

$$2.125\ in * \left(\frac{2000\ ft}{0.53\ in}\right) = 8{,}018.9\ ft\ (L_{orange})$$

Convert Elevation (m) to Elevation (ft):

Known: 1 m = 3.28 ft

$$680\ m * \frac{3.28\ ft}{1\ m} = 2{,}230.4\ ft\ (y_{blue})$$

$$580\ m * \frac{3.28\ ft}{1\ m} = 1{,}902.4\ ft\ (y_{black})$$

$$510\ m * \frac{3.28\ ft}{1\ m} = 1{,}672.8\ ft\ (y_{green})$$

$$610\ m * \frac{3.28\ ft}{1\ m} = 2{,}000.8\ ft\ (y_{orange})$$

Find Slopes:

Assume: y_{center} = 400 m = 1,312 ft

$$Slope, Y = \frac{\Delta Y}{\Delta X}$$

$$\frac{y_{blue} - y_{center}}{L_{blue}} = \frac{2{,}230.4 - 1{,}312}{8528.3} = 0.108 = 10.8\%$$

$$\frac{y_{black} - y_{center}}{L_{black}} = \frac{1{,}902.4 - 1{,}312}{6{,}226.4} = 0.095 = 9.5\%$$

$$\frac{y_{green} - y_{center}}{L_{green}} = \frac{1{,}672.8 - 1{,}312}{8{,}490.6} = 0.042 = 4.2\%$$

$$\frac{y_{orange} - y_{center}}{L_{orange}} = \frac{2{,}000.8 - 1{,}312}{8{,}018.9} = 0.086 = 8.6\%$$

Find Average Slope, Y:

$$Y = \frac{0.108 + 0.095 + 0.042 + 0.086}{4} = 0.083 = 8.3\%$$

Calculate Lag Time, t_L:

$$t_L = \frac{L^{0.8}(S+1)^{0.7}}{1{,}900 * Y^{0.5}}$$

Use: L = L_{blue} (from previous figure) = 8,528.3 ft**

**Note: L_{blue} = the length from the channel bottom to the most remote point on watershed.

Assume: Circular watershed

$$L = r = \sqrt{\frac{A}{\pi}}$$

$$\sqrt{\frac{5.31\ km^2}{\pi}} = 1.3\ km = 4{,}297.9\ ft$$

Calculate S:

$$S = \frac{1{,}000}{CN} - 10$$

Given:

Row ID	Station ID	Stations	Record Length	Drainage Area (km^2)	Land Cover	Soil Types	Land Cover	Maximum Peak Discharge (m^3/s)	Unit Peak Discharge (m^3/s / km2)	Runoff CN
7	3	Cuba	22	326	B-C	B55-C45	3.5	2160	6.62576687	71.725
116	03BA003	Jamaica	36	518	A19-C10-D61-E8	A70-D30	2.54	1790	3.45559846	66.565
120	50029000	Puerto Rico	47	518	B35-C25-D25-E15	B75-C25	2.8	5520	10.6563707	75.1
121	50045010	Puerto Rico	12	448	B35-C25-D25-E15	C100	2.8	5580	12.4553571	81.4
123	50144000	Puerto Rico	38	244	B35-C25-D25-E15	C100	2.8	4620	18.9344262	81.4
6	2	Cuba	23	540	C-D	A60-C25-D15	2.5	3015	5.58333333	68.275
5	1	Cuba	15	753	B-C	B55-C45	3.5	2760	3.66533865	71.725

Reference:

Runoff Curve Numbers (McCuen 2005)				
Land Cover	Soil Type			
	A	B	C	D
A: thick forest	32	58	72	79
B: sparse forest, wooded savannah	44	65	76	82
C: meadows, savannah with few or no trees	49	69	79	84
D: cultivated land	67	78	85	89
E: bare, soil, urban zones	84	90	92	94

From both reference tables; Assume: CN=74

$$S = \frac{1{,}000}{74} - 10 = 3.5$$

Put recently found numbers into lag time equation:

$$t_L = \frac{8{,}528.3^{0.8} * (3.5+1)^{0.7}}{1{,}900 * 8.3^{0.5}} = 0.731\ hrs$$

$$t_L = \frac{4{,}297.9^{0.8} * (3.5+1)^{0.7}}{1{,}900 * 8.3^{0.5}} = 0.422\ hrs$$

Calculate Time of Concentration, t_C:

$$\frac{5}{3} * t_L = \frac{5}{3} * 0.731 = 1.21\ hrs \rightarrow 1\ hr\ 12.6\ min$$

$$\frac{5}{3} * t_L = \frac{5}{3} * 0.422 = 0.703\ hrs \rightarrow 42.2\ min$$

Find Intensity, i; from IDF curve:

Reference:

Rainfall Intensity-Duration-Frequency

Figure 4-4: Rainfall Intensity-Duration-Frequency, Baltimore, MD. After (McCuen, 2004)

i = 3.7 in/hr
i = 4.0 in/hr
} Intensity range of small watershed

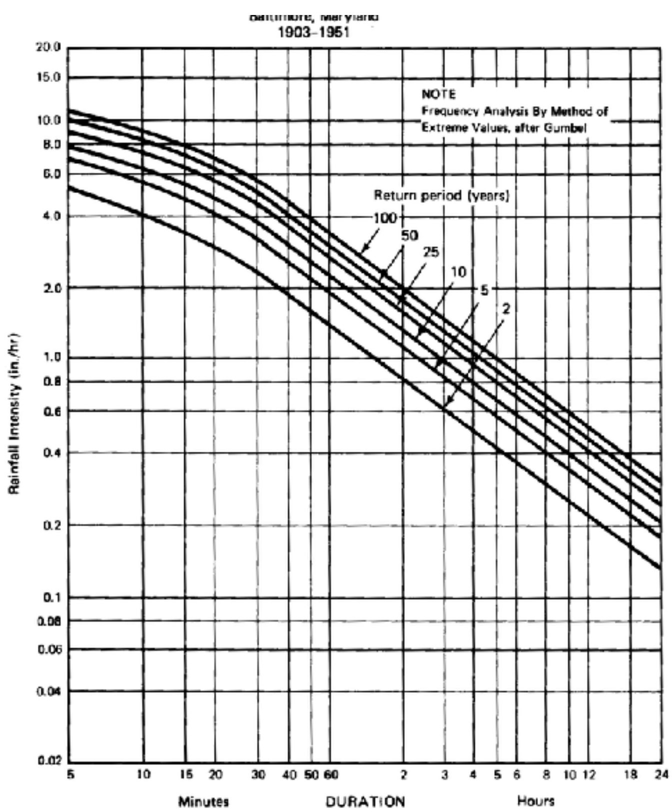


FIGURE 4–4 Rainfall intensity-duration-frequency. (National Weather Service, 1961.)

<u>**Calculations for Larger Watershed**</u>

Calculate Lag Time, t_L:

$$t_L = \frac{L^{0.8}(S+1)^{0.7}}{1{,}900 * Y^{0.5}}$$

Determine: L

Assume: Circular Watershed

$$L = r = \sqrt{\frac{A}{\pi}}$$

Given: A = 1200 km^2

$$L = \sqrt{\frac{1{,}200\ km^2}{\pi}} = 19.5\ km$$

Convert Length (km) to Length (ft):

$$19.5\ km * \frac{3{,}280.8\ ft}{km} = 63{,}976.4\ ft$$

Assume: Y = 6%

Reference:

Rodier, J. A., M. Roche, and Reginald W. Herschy. World Catalogue of Maximum Observed Floods / Répertoire Mondial Des Crues Maximales Observées / Composé [i.e. Revisé] Par Reg Herschy. Wallingford, Oxfordshire: International Association of Hydrological Sciences, 1984. Print.

→Relatively Steep Slopes Y>5%

Assume: CN is the same for both watersheds ∴ CN = 74; S = 3.5

$$t_L = \frac{63{,}976.4^{0.8}(3.5+1)^{0.7}}{1{,}900 * 6^{0.5}} = 4.31\ hrs$$

Find Time of Concentration, t_C:

$$\frac{5}{3} * t_L = \frac{5}{3} * 4.31 = 7.18\ hrs$$

Determine intensity, i, from IDF curve (for large watershed):

i = 0.65 in/hr

Determine: Ratio Multiplier

Find Intensity Ratio:

$$Intensity\ Ratio = \frac{i_{small\ watershed}}{i_{large\ watershed}} = \frac{3.7\frac{in}{hr}}{0.65\frac{in}{hr}} = 5.69 \qquad \frac{4.0\frac{in}{hr}}{0.65\frac{in}{hr}} = 6.15$$

Find Overall Ratio Multiplier:

Reference:

Asquith, William H. Areal-Reduction Factors for the Precipitation of the 1-Day Design Storm in Texas. U.S. GEOLOGICAL SURVEY, Water-Resources Investigations Report 99-4267.

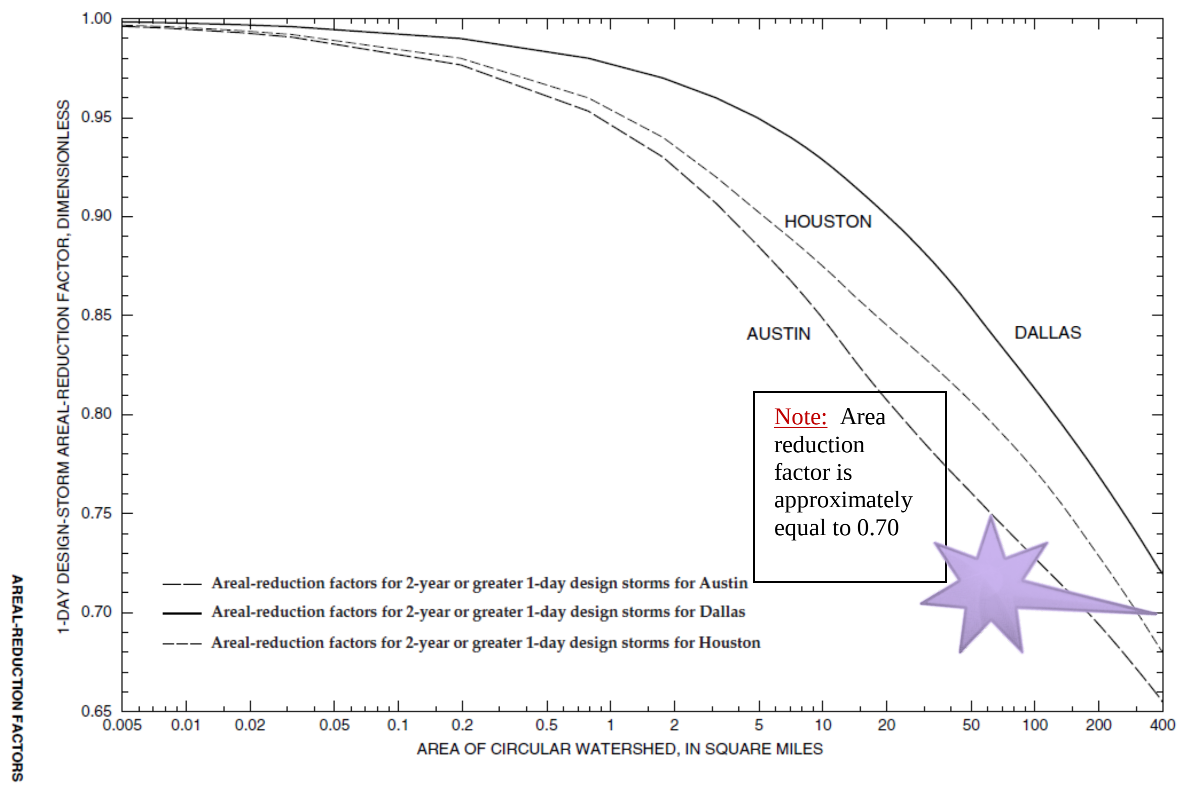


Figure 18. Areal-reduction factors for 2-year or greater 1-day design storms for small circular watersheds for Austin, Dallas, and Houston, Texas.

$$Intensity\ Ratio * (inverse) Watershed\ Area\ Reduction\ Factor = 5.69 * \frac{1}{.7} = 8.13$$

$$6.15 * \frac{1}{.7} = 8.79 \ \therefore RANGE\ of\ ratio\ multiplier \approx \{8.13 - 8.79\}$$

Calculate: Slope of Channel, S_o

$$Slope = \frac{\Delta Y}{\Delta X}$$

$$= \frac{973.5' - 965.14'}{243.72'} = 0.0343 = 3.43\%$$

Note: elevations and distances are from on-site topographic map

Estimate: Roughness, n

Use: Float Method Velocity (length versus time)

$$v = 1.5\frac{ft}{s}$$

Determine: Area, A and Wetted Perimeter, P_w of Cross-Section of River at Bridge Axis

$$A = By_n + SSy_n$$

$$(12')(1') + (3')(1')^2 = 15\ ft^2$$

$$P_w = B + 2y_n * \sqrt{1 + SS^2}$$

$$12' + 2(1')\sqrt{1 + 3^2} = 18.32\ ft$$

Use: Manning's Equation

$$V = \frac{Cm}{n} * R_0^{2/3} * S_o^{1/2}$$

Assume: Cm=1.49; English Units

$$1.5\frac{ft}{s} = \frac{1.49}{n}\left(\frac{15\ ft^2}{18.32\ ft}\right)^{2/3} (0.0343)^{1/2}$$

Solve for n:

$$n = 0.16$$

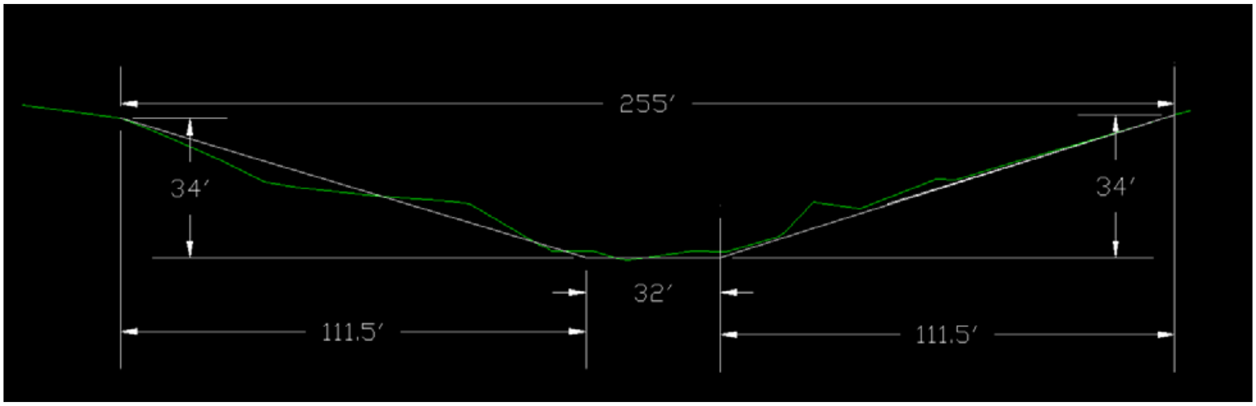
Refer to Table 5.1, page 256 in Water Resources Engineering

Natural Channels, Brush, Irregular: Roughness Range, $n = \{0.07 - 0.16\}$

→Choose: $\mathbf{n = 0.115}$

Trial and Error

Bridge Profile: Simplified into Trapezoidal Channel



Determine: Side Slope, SS

$$SS = \frac{\Delta X}{\Delta Y}$$

$$\frac{111.5'}{34'} = 3.28$$

Equations Needed: Cross-Sectional Area, A and Wetted Perimeter, P_w

$$A = By_n + SSy_n^2$$

$$P_w = B + 2y_n\sqrt{1 + SS^2}$$

Using Manning's Equation, Determine: Depth of Flow, y_n

$$Q = \frac{1.49}{n} * AR_0^{2/3} * S_o^{1/2}$$

Assume: $Q_{MAX\ FLOOD(LOW\ ESTIMATE)}$=465.64 cfs*8.13=3,785.65 cfs

n=0.115

S_o=0.0343

Re-arrange Manning's Equation:

$$AR^{2/3} = \frac{Qn}{1.49 * S_o^{1/2}}$$

$$\frac{A^{5/3}}{P^{2/3}} = \frac{3{,}785.65\ cfs * 0.115}{1.49\left(0.0343^{1/2}\right)} = 1{,}577.63 \therefore \frac{(32y_n + 3.28y_n^2)^{5/3}}{\left(32 + 2y_n * \sqrt{1 + 3.28^2}\right)^{2/3}} = 1{,}577.63$$

Assume: $Q_{MAX\ FLOOD(HIGH\ ESTIMATE)}$=465.64 cfs*8.79=4,092.98 cfs

$n=0.115$

$S_o=0.0343$

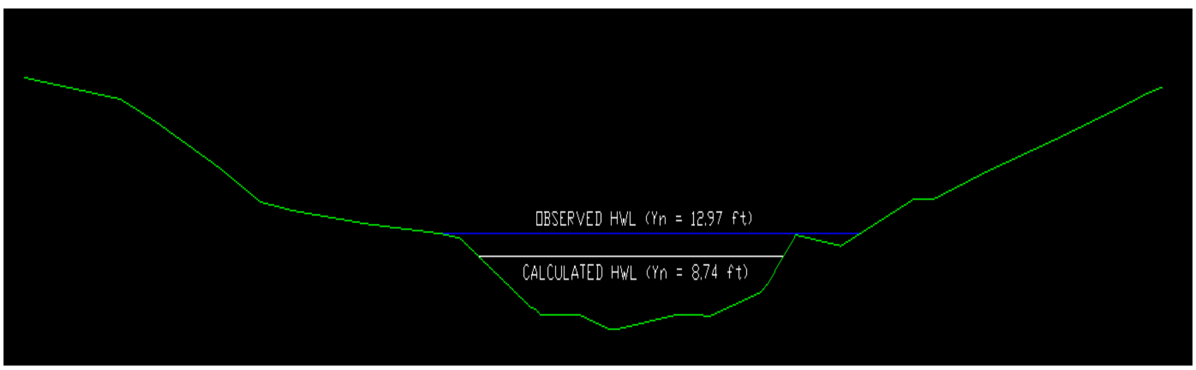
Re-arrange Manning's Equation:

$$AR^{2/3} = \frac{Qn}{1.49 * S_o^{1/2}}$$

$$\frac{A^{5/3}}{P^{2/3}} = \frac{4{,}092.98\ cfs * 0.115}{1.49\left(0.0343^{1/2}\right)} = 1{,}705.71 \therefore \frac{(32y_n + 3.28y_n^2)^{5/3}}{\left(32 + 2y_n * \sqrt{1+3.28^2}\right)^{2/3}} = 1{,}705.71$$

Solve for y_n Using Trial and Error: ≈ {1,578-1,705.71}

y_n (ft)	$AR^{2/3}$		y_n (ft)	$AR^{2/3}$	
6	812.18		8	1427.65	
7	1096.03		8.5	1612.11	
7.5	1255.73		8.6	1650.54	
8	1427.65		8.7	1689.47	
8.1	1463.53		8.71	1693.39	
8.2	1499.92		8.72	1697.32	
8.3	1536.81		8.73	1701.25	
8.4	1574.20		8.74	1705.19	
8.41	1577.97	**OK**	**8.741**	1705.59	**OK**



Observed Flood Level = 12.97 ft

Based on the world catalog of maximum observed floods, a high water level was determined for our watershed. Compared to the observed flood level by the inhabitants of Chichica, the calculated flood levels are less than the observed value and will be used as lower limits.

APPENDIX E: CABLE CHARACTERISTICS

SYMBOLS

l	Bridge Span, distance between tower axes
C_d	Camber, vertical distance from the spanning cable anchorage (top of walkway and tower foundation minus 0.25m) and the highest point the spanning cable
F, f	Sag, vertical distance from tower saddle to the lowest point of the main cable
h_t	Tower height, vertical distance between top of walkway and tower foundation and saddle cable
σ_m	Diameter of main cables
σ_s	Diameter of spanning cables
g	full load in (tonnes/m)
T	Main cable tension at saddle for front stays (all main cables)
T_{perm}	Permissible cable tension
θ	Front stay cable inclination at saddle
θ_{fo}	Initial approximation of θ_f
β_f	Backstay cable inclination = front stay cable inclination at saddle for full load
E	Modulus of elasticity of cables
D_L, D_R	Backstay distance for main cables, distance between tower axis and hinge of the main cable anchorage(front of main cable anchorage for the design drawing 46/1
L	Length of main cables between cables
L_{total}	Total main cable length between main cable anchorages
Δ_f	
$\Delta_{D.R}, \Delta_{D.L}$	Increase / Decrease of f, DR, DL, D, L due to changing load
Δ_D	
Δ_L	
p	live load (tonnes/m)
P_s	Pretension of spanning cables (both spanning cables) expressed as equally distributed load in (tonnes/m)
n	Number of cables
$L_{overlap}$	Overlap cable length at terminals
L_{cutoff}	Cutoff cable length

Indices:

h	hoisting load
d	dead load
f	full load
R	right bank
L	left bank
i, f_o	Initial State

$ORIGIN := 1$

$tonnes := 1000kg$

Bridge Span

$l := 56.69m = 185.991 \cdot ft$

Dead Load camber

$C_d := 0.03l = 1.701 \cdot m$

$C_d = 5.58 \cdot ft$

Dead load Sag

$f_d := 0.12l = 6.803\,m$

$f_d = 22.319 \cdot ft$

Theoretical tower height

$h_{t_1} := f_d + C_d + 1.05m = 9.553\,m$

$h_{t_1} = 31.344 \cdot ft$

Table 45 (Page 171)

Select Standard Tower case #3

Main cables:	$n := 2$	$\sigma_m := 36mm$	$\sigma_m = 1.417 \cdot in$
2. Spanning Cables:	$n = 2$	$\sigma_s := 26mm$	$\sigma_s = 1.024 \cdot in$
3. Tower Height:	$h_t := 9.20m$	$h_t = 30.184 \cdot ft$	

Effective dead load sag

$f_d := h_t - 1.05m - C_d = 6.449\,m$ $\quad f_d = 21.159 \cdot ft$

$\frac{f_d}{l} = 0.114$ which is in the range of (0.09,0.137). **Checked!**

Select gf (Table Pg. 172)

$g_{f.i} := 0.618 \frac{tonnes}{m}$

Calculate full load cable tension

$T_f := g_{f.i} \cdot \frac{l^2}{8.4f_d} \cdot \sqrt{1 + 17.64 \cdot \left(\frac{f_d}{l}\right)^2} = 40.631 \cdot tonnes$, which is less than T_{perm} = 46 tonnes.

We will use n=2, σ M=36mm main cables. (T_{perm}= 46 tonnes)

Find θ_{fo} to locate the main cable anchorage

$$4.2\frac{f_d}{l} = 0.478$$

$$\text{atan}(0.478) = 25.548 \cdot \text{deg}$$

$$\theta_{fo} := 25.548\text{deg}$$

Diameter of Spanning cables (Table 45, Pg 171)

$n = 2$ $\sigma_s = 1.024 \cdot \text{in}$

Assume Modulus of Elasticity ("apparent" not Young's Modulus) E=10.5-16 tonnes/mm^2

Assume 11.5 based on sample calcs from reference text

$$E := 11.5\frac{\text{tonnes}}{\text{mm}^2} \qquad E = 1.636 \times 10^7 \cdot \frac{\text{lb}}{\text{in}^2}$$

Back Stay distances of Left and Right Banks ($D_{L/R}$)

$$D_L := 19.7\frac{\text{ft}}{\tan(\theta_{fo})} = 41.213 \cdot \text{ft} \qquad D_L = 12.562\,\text{m}$$

$$D_R := 20.48\frac{\text{ft}}{\tan(\theta_{fo})} = 42.845 \cdot \text{ft} \qquad D_R = 13.059\,\text{m}$$

Loading

Hoisting load gh

$n = 2$ $\sigma_m := 36\text{mm}$ $\sigma_s = 26 \cdot \text{mm}$

$$g_h := 0.00038058\frac{\text{tonnes}}{\text{m} \cdot \text{cm}^2} n \cdot \sigma_m^2 = 9.865 \times 10^{-3} \cdot \frac{\text{tonnes}}{\text{m}} \qquad g_h = 3.314 \times 10^{-3} \cdot \frac{\text{ton}}{\text{ft}}$$

2. Dead Load gd

$$g_h = 9.865 \times 10^{-3} \cdot \frac{\text{tonnes}}{\text{m}} \qquad g_{walk} := 0.088\frac{\text{tonnes}}{\text{m}}$$

$$g_{wire} := 0.006\frac{\text{tonnes}}{\text{m}} \qquad g_{hand} := 0.003\frac{\text{tonnes}}{\text{m}}$$

$$g_{suspender} := 0.017\frac{\text{tonnes}}{\text{m}}$$

$$g_s := 0.00038058\frac{\text{ton}}{\text{m} \cdot \text{cm}^2} n \cdot \sigma_s^2 = 4.668 \times 10^{-3} \cdot \frac{\text{tonnes}}{\text{m}}$$ (Spanning Cables)

$$g_d := g_h + g_{walk} + g_{hand} + g_{wire} + g_{suspender} + g_s = 0.129 \cdot \frac{\text{tonnes}}{\text{m}} \qquad g_d = 0.043 \cdot \frac{\text{ton}}{\text{ft}}$$

3. Live load p

$$p := 0.48 \frac{tonnes}{m}$$

4. Full load gf

$$g_f := g_d + p = 0.609 \cdot \frac{tonnes}{m} \qquad g_f = 0.204 \cdot \frac{ton}{ft} \qquad \frac{g_f}{1.2m} = 103.864 \cdot \frac{lb}{ft^2}$$

Pretensions in spanning cables

$$P_s := 0.1 g_d = 0.013 \cdot \frac{tonnes}{m} \qquad P_s = 4.318 \times 10^{-3} \cdot \frac{ton}{ft}$$

Full load sag and Hoisting load sag

$$F_f := 6.797m \qquad F_h := 6.265m$$

Cable inclination at saddles

$$4 \frac{F_f}{l} = 0.48$$

$$\text{atan}(0.48) = 25.641 \cdot deg$$

$$\beta_f := 25.641deg$$

Cable tension in main cables

$$T_f := g_f \cdot \frac{l^2}{8 \cdot F_f} \cdot \sqrt{1 + 16 \cdot \left(\frac{F_f}{l}\right)^2} = 39.888 \cdot tonnes \qquad T_f = 43.969 \cdot ton$$

Use for selecting main cables,Tf is for both cables

$$T_h := g_h \cdot \frac{l^2}{8 \cdot F_h} \cdot \sqrt{1 + 16 \cdot \left(\frac{F_h}{l}\right)^2} = 0.692 \cdot tonnes$$

$$T_h = 0.762 \cdot ton$$

Displacement of Saddles

Hosting load

$$\Delta_{D.R} := -0.035m$$

$$\Delta_{D.L} := -0.032m$$

2. Full load

$\Delta_{DR} := 0.032m$

$\Delta_{DL} := 0.031m$

Cable Length (Excluding overlapping length at terminals)

$L_{total} := 87.006m$

Cable Length (Including overlapping length at terminals)

$L_{overlap} := 1.75m$

(Page 50, Krahenbuhl & Wagner) with diameter 36mm, 7 Bulldog Grips, Gap 210mm

$L_{cutoff} := L_{total} + 2 \cdot L_{overlap} = 90.506\,m$

$L_{cutoff} = 296.936 \cdot ft$

APPENDIX F: TOWER DESIGN CALCULATIONS

SYMBOLS

l	Bridge Span, distance between tower axes
c	Camber
F, f	Sag, vertical distance from tower saddle to the lowest point of the main cable
h_t	Tower height, vertical distance between top of walkway and tower foundation and saddle cable
σ_m	Diameter of main cables
σ_s	Diameter of spanning cables
x	Horizontal displacement of the bridge center under wind load
T_S	Maximum tension in spanning cables
T_H	Horizontal component of the spanning cable tension in the direction of bridge axis
θ	Front stay cable inclination at saddle
θ_{fo}	Initial approximation of θ_f
β_f	Backstay cable inclination = front stay cable inclination at saddle for full load
E	Modulus of elasticity of cables
D_L, D_R	Backstay distance for main cables, distance between tower axis and hinge of the main cable anchorage(front of main cable anchorage for the design drawing 46/1
L_M	Length of main cables between saddles
L_S	Length of spanning cables between tower axes
Δ_f $\Delta_{D.R}$, $\Delta_{D.L}$ Δ_D Δ_L	Increase / Decrease of f, DR, DL, D, L due to changing load
P_s	Pretension of spanning cables (both spanning cables) expressed as equally distributed load in (tonnes/m)
n	Number of cables
A	Total Cross-Sectional Area of cables
G_t	Dead weight of tower
c_ratio	Center distance of tower legs

α_1	Inclination angle of the plane of the spanning cables under wind load in relation to the vertical
γ_1	Inclination angle of the plane of the main cables under wind load in relation to the vertical
H	Horizontal component of the main cable tension (all main cables)
H_w	Horizontal load on top of towers
V	Vertical load on top of towers
P_1	Vertical reaction at tower base, tower leg 1
P_2	Vertical reaction at tower base, tower leg 2
P_H	Horizontal reaction at tower base
T_S	Maximum tension in spanning cables
T_H	Horizontal Component of the spanning cable tension in the direction of the bridge axis
T_V	Vertical component of the spanning cable tension
T_{ps}	Pretension in sideway cables
$L_{overlap}$	Overlap cable length at terminals
L_{cutoff}	Cutoff cable length
k	Integral factor for average tension along cable
P_{M_1}	Load on main cables under wind
P_{S_1}	Load on spanning cables under wind

Indices

h	hoisting load
d	dead load
f	full load
R	right bank
L	left bank
i, f_o, o	Initial State

Tower Calculation

Initial Layout data

$ORIGIN := 1$

$tonnes := 1000kg$

$l := 56.69m$

$h_t := 9.20m$

$f_d := 6.45m$

$g_d := 0.129 \frac{tonnes}{m}$

$c\_ratio := 3.50m$

$\sigma_m := 36mm$

$F_f := 6.797m$

$g_f := 0.609 \frac{tonnes}{m}$

$n := 2$

$\sigma_s := 26mm$

$E := 11.5 \frac{tonnes}{mm^2}$

$A := 537.23mm^2$

$C_d := 1.7m$

$\beta_f := 25.641deg$

Calculate total section Area

$$A_m := 2A = 1.074 \times 10^3 \cdot mm^2$$

$$A_s := 2 \cdot 280.22mm^2 = 560.44 \cdot mm^2$$

Calculate initial cable lengths:

Load case A-----Dead load (Full load)

Calculate initial cable lengths:

$f_o := f_d$

$w := 0.1 \frac{tonnes}{m}$

$C_o := C_d$

$$L_{mo} := l \cdot \left[1 + \frac{8}{3}\left(\frac{f_o}{l}\right)^2 - \frac{32}{5} \cdot \left(\frac{f_o}{l}\right)^4\right] = 58.586\,m$$ (Main cables)

$$L_{so} := l \left[1 + \frac{8}{3}\left(\frac{C_o}{l}\right)^2\right] = 56.826\,m$$ (Spanning Cables)

Pretension in spanning cables

$$P_s := 0.1 \cdot g_d = 0.013 \cdot \frac{tonnes}{m}$$

$$w_1 := w \cdot \left(0.232 + \frac{0.0075}{m} h_t\right) = 0.03 \cdot \frac{tonnes}{m}$$

Calculate the displacement x and sag f (Loading cases iteration)

Step 0:

$$x := 0.015l = 0.85\,m$$

$$f_1 := 1.002f_o = 6.463\,m$$

Step 1:

.
$$\frac{x}{f_1 + 1.30m} = 0.11$$

$$\gamma_1 := \operatorname{asin}(0.11)$$

$$\gamma_1 = 6.315 \cdot deg$$

2.
$$\frac{x}{0.25m + h_t - \cos(\gamma_1)(f_1 + 1.3m)} = 0.49$$

$$\alpha_1 := \operatorname{atan}(0.49)$$

$$\alpha_1 = 26.105 \cdot deg$$

$$C_1 := \frac{x}{\sin(\alpha_1)} = 1.933\,m$$

Step 2:

$$L_{M_1} := l \cdot \left[1 + \frac{8}{3} \cdot \left(\frac{f_1}{l}\right)^2 - \frac{32}{5} \cdot \left(\frac{f_1}{l}\right)^4\right] = 58.594\,m$$

$$L_{S_1} := l \cdot \left[1 + \frac{8}{3} \cdot \left(\frac{C_1}{l}\right)^2\right] = 56.866\,m$$

$$k_1 := 1.04$$

$$P_{M_1} := 8f_1E \cdot A_m \cdot \frac{L_{M_1} - L_{mo}}{k_1 \cdot L_{mo}l^2} + g_d + P_s = 0.166 \cdot \frac{tonnes}{m}$$

$$k_2 := 1.003$$

$$P_{S_1} := 8C_1E \cdot A_s \cdot \frac{L_{S_1} - L_{so}}{k_2 \cdot L_{so}l^2} + P_s = 0.035 \cdot \frac{tonnes}{m}$$

Step 3:

$$newf_1 := f_o + (f_1 - f_o) \cdot \frac{g_d}{P_{M_1} \cdot \cos(\gamma_1) - P_{S_1} \cdot \cos(\alpha_1)} = 6.462\,m$$

$$newx := x \cdot \frac{w_1}{P_{M_1} \sin(\gamma_1) + P_{S_1} \sin(\alpha_1)} = 0.766\,m$$

$$newf_1 - f_1 = -4.694 \times 10^{-4}\,m$$

this is less than 0.002.

So we will use the sag=6.462m

$$DispalcementA := \frac{(x + newx)}{2} = 0.808\,m$$

Calculate the final data for load case A

1. Dead Weight of single tower

$$G_t := 0.4tonnes + 0.01 \frac{tonnes}{m^2} h_t^2 = 1.246 \cdot tonnes$$

$$G_t = 1.374 \cdot ton$$

2. Vertical Load on top of the towers (V/2 for each tower)

$$V := P_{M_1} \cdot \frac{1}{2} \cdot \cos(\gamma_1) \cdot \left(1 + l \cdot \frac{\tan(\beta_f)}{4\,newf_1 \cdot \cos(\gamma_1)}\right) = 9.622 \cdot tonnes$$

$$V = 10.607 \cdot ton$$

3. Horizontal load on top of the towers

$$H_w := P_{M_1} \cdot \frac{1}{2} \cdot \sin(\gamma_1) = 0.517 \cdot tonnes$$

$$H_w = 0.57 \cdot ton$$

4. Reactions at the tower base (Loads on walkway and tower foundation)

$$P_1 := \frac{V}{2} + \frac{G_t}{2} - \frac{H_w \cdot h_t}{c\_ratio} - \frac{1.025 \cdot w_1 \cdot h_t^2}{c\_ratio} = 3.329 \cdot tonnes$$

$$P_1 = 3.669 \cdot ton$$

$$P_2 := \left[\left(\frac{V}{2} + \frac{G_t}{2}\right) + \frac{H_w \cdot h_t}{c\_ratio}\right] + \frac{1.025 \cdot w_1 \cdot h_t^2}{c\_ratio} = 7.54 \cdot tonnes$$

$$P_2 = 8.311 \cdot ton$$

$$P_H := H_w + 2.05 w_1 \cdot h_t + \frac{P_{S_1} \cdot l}{2} \cdot \sin(\alpha_1) = 1.515 \cdot tonnes$$

$$P_H = 1.67 \cdot ton$$

$$T_{sv} := \frac{P_{S_1} \cdot l}{2} \cdot \cos(\alpha_1) = 0.879 \cdot tonnes$$

$$T_{sv} = 0.968 \cdot ton$$

$$T_{sh} := \frac{P_{S_1} \cdot l^2}{8C_1} = 7.175 \cdot tonnes$$

$$T_{sh} = 7.909 \cdot ton$$

5. Maximum tension in spanning cables (both cables):

$$T_s := \frac{P_{S_1} \cdot l^2}{8C_1} \cdot \sqrt{1 + 16 \cdot \left(\frac{C_1}{l}\right)^2} = 7.241 \cdot \text{tonnes}$$

$$T_s = 7.982 \cdot \text{ton}$$

Capacity Check for load case A

$$V = 9.622 \cdot \text{tonnes}$$

$$H_w = 0.517 \cdot \text{tonnes}$$

$$h_t = 9.2\,\text{m}$$

Pg194, Krahenbuhl & Wagner**.**
O.K. Checked!

Calculate initial cable lengths:

__**Load case B-----Dead load (W/3+Full load)**__

Calculate initial cable lengths:

$$f_o := F_f \qquad w := 0.033\frac{\text{tonnes}}{\text{m}} \qquad C_f := h_t - 1.05\text{m} - F_f = 1.353\,\text{m}$$

$$C_o := C_f$$

$$L_{mo} := l \cdot \left[1 + \frac{8}{3}\left(\frac{f_o}{l}\right)^2 - \frac{32}{5} \cdot \left(\frac{f_o}{l}\right)^4\right] = 58.788\,\text{m}$$ (Main cables)

$$L_{so} := l\left[1 + \frac{8}{3}\left(\frac{C_o}{l}\right)^2\right] = 56.776\,\text{m}$$ (Spanning Cables)

Pretension in spanning cables

$$Ps := 0 \cdot \frac{\text{tonnes}}{\text{m}}$$

$$w_1 := w \cdot \left(0.232 + \frac{0.0075}{\text{m}}h_t\right) = 9.933 \times 10^{-3} \cdot \frac{\text{tonnes}}{\text{m}}$$

Calculate the displacement x and sag f (Loading cases iteration)

Step 0:

$$x := 0.0025l = 0.142\,m$$

$$f_1 := 1.002f_o = 6.811\,m$$

Step 1:

$$\frac{x}{f_1 + 1.30m} = 0.017$$

$$\gamma_1 := \text{asin}(0.017)$$

2.

$$\frac{x}{0.25m + h_t - \cos(\gamma_1)(f_1 + 1.3m)} = 0.106$$

$$\alpha_1 := \text{atan}(0.106)$$

$$C_1 := \frac{x}{\sin(\alpha_1)} = 1.345\,m$$

Step 2:

$$L_{M_1} := l \cdot \left[1 + \frac{8}{3} \cdot \left(\frac{f_1}{l}\right)^2 - \frac{32}{5} \cdot \left(\frac{f_1}{l}\right)^4\right] = 58.796\,m$$

$$L_{S_1} := l \cdot \left[1 + \frac{8}{3} \cdot \left(\frac{C_1}{l}\right)^2\right] = 56.775\,m$$

$$P_{M_1} := 8f_1E \cdot A_m \cdot \frac{L_{M_1} - L_{mo}}{k_1 \cdot L_{mo} l^2} + g_f + P_s = 0.65 \cdot \frac{tonnes}{m}$$

$$P_{S_1} := 8C_1E \cdot A_s \cdot \frac{L_{S_1} - L_{so}}{k_2 \cdot L_{so} l^2} + P_s = 0.012 \cdot \frac{tonnes}{m}$$

Step 3: $$newf_1 := f_o + (f_1 - f_o) \cdot \frac{g_f}{P_{M_1} \cdot \cos(\gamma_1) - P_{S_1} \cdot \cos(\alpha_1)} = 6.81\,m$$

$$newx := x \cdot \frac{w_1}{P_{M_1} \sin(\gamma_1) + P_{S_1} \sin(\alpha_1)} = 0.114\,m$$

$$newf_1 - f_1 = -6.003 \times 10^{-4}\,m$$ this is less than 0.002.

So we will use the sag=6.81m

$$DisplacementB := \frac{(x + newx)}{2} = 0.128\,m$$

Calculate the final data for load case B

1. Dead Weight of single tower

$$Gt := 0.4tonnes + 0.01\frac{tonnes}{m^2} h_t^{\,2} = 1.246 \cdot tonnes$$

$$Gt = 1.374 \cdot ton$$

2. Vertical Load on top of the towers (V/2 for each tower)

$$V := P_{M_1} \cdot \frac{1}{2} \cdot \cos(\gamma_1) \cdot \left(1 + l \cdot \frac{\tan(\beta_f)}{4\,newf_1 \cdot \cos(\gamma_1)}\right) = 36.807 \cdot tonnes$$

$V = 40.572 \cdot ton$ Vertical load worst case **control**

3. Horizontal load on top of the tower

$$H_w := P_{M_1} \cdot \frac{1}{2} \cdot \sin(\gamma_1) = 0.313 \cdot tonnes$$

4. Reactions at the tower base
(Loads on walkway and tower foundation)

$$P_1 := \frac{V}{2} + \frac{G_t}{2} - \frac{H_w \cdot h_t}{c\_ratio} - \frac{1.025 \cdot w_1 \cdot h_t^{\,2}}{c\_ratio} = 17.957 \cdot tonnes$$

$$P_2 := \left[\left(\frac{V}{2} + \frac{G_t}{2}\right) + \frac{H_w \cdot h_t}{c\_ratio}\right] + \frac{1.025 \cdot w_1 \cdot h_t^{\,2}}{c\_ratio} = 20.096 \cdot tonnes$$

$$P_H := H_w + 2.05 w_1 \cdot h_t + \frac{P_{S_1} \cdot l}{2} \cdot \sin(\alpha_1) = 0.538 \cdot tonnes$$

$$T_{sv} := \frac{P_{S_1} \cdot l}{2} \cdot \cos(\alpha_1) = 0.352 \cdot tonnes$$

$$T_{sh} := \frac{P_{S_1} \cdot l^2}{8C_1} = 3.733 \cdot tonnes$$

5. Maximum tension in spanning cables (both cables):

$$T_s := \frac{P_{S_1} \cdot l^2}{8C_1} \cdot \sqrt{1 + 16 \cdot \left(\frac{C_1}{l}\right)^2} = 3.749 \cdot \text{tonnes}$$

Capacity Check for load case B

$V = 36.807 \cdot \text{tonnes}$

$H_w = 0.313 \cdot \text{tonnes}$

$h_t = 9.2\,\text{m}$

Pg 194 Krahenbuhl & Wagner
O.K. Checked!

APPENDIX G: FOUNDATION AND WALKWAY DESIGN CALCULATIONS

SYMBOLS

B, L, H	Open dimensions of foundation
P_1, P_2, P_H, T_{sv}, T_{sh}	Loads on foundation from tower calculation for loading case A and B
w_1	Partial weights of foundation block
h_a, φ	Height of inclination of backfilling soil measured either from the foundation base or from the rock face
h_p, ε	Height of inclination of ground surface in front of foundation, measured either from the foundation base or from the rock face
h_{ra}, h_{rp}	Height of the rock face at the back (hra) or the front (hrp) of the foundation, measured from foundation base
h_w	Distance of the ground water level from the foundation base
γ_1, γ_2	Unit weight of moist soil. γ_1: subsoil , γ_2: backfilling
Φ	Angle of internal friction of soil
γ_c	Unit weight of concrete / masonry
γ_w	Unit weight of water
w_u	Uplift due to ground water
δ	Angle of wall friction
λ_{ah}	Active horizontal earth pressure coefficient
E_{ah}	Active horizontal earth pressure
E_{av}	Active vertical earth pressure
R_v	Vertical component of R
M_x, M_y	Sum of static moments of all acting forces in the center of the foundation base

e_x, e_y	Eccentricity of resultant loading force at the foundation base
u, v	Distance of the resultant loading force from the edge of the foundation base
δ_R	Inclination of R towards vertical
Z	Factor for the calculation of δ_{max}
$F_{.sl}$	Safety factor against sliding
S_q, S_γ	Shape correcting coefficients
g_ε	Topographical correcting coefficient
N_γ, N_q	Ground bearing - capacity coefficients
Q_v	Shear resistance of ground
F_{BC}	Safety factor against shear failure of ground

$ORIGIN := 1$ $\quad$ $tonnes := 1000kg$

Walkway and Tower foundation

North Bank:

Loads

Loading cases:

	A	B
	$P_{a_1} := 3.329 tonnes$	$P_{b_1} := 17.957 tonnes$
	$P_{a_2} := 7.54 tonnes$	$P_{b_2} := 20.096 tonnes$
	$P_{H.a} := 1.515 tonnes$	$P_{H.b} := 0.538 tonnes$
	$Ta_{sv} := 0.879 tonnes$	$Tb_{sv} := 0.352 tonnes$
	$Ta_{sh} := 7.175 tonnes$	$Tb_{sh} := 3.733 tonnes$

Type of foundation

	A	B
	Without foot in soil (rectangular)	Without foot in soil (rectangular)

Dimensions

	A	B
	$B_a := 14ft = 4.267 m$	$B_b := 14ft$
	$L_a := 18.5ft = 5.639 m$	$L_b := 18.5ft$
	$H_a := 13ft = 3.962 m$	$H_b := 13ft$

From topographic survey

	A	B
	$ha_a := 13ft = 3.962 m$	$ha_b := ha_a$
	$hp_a := 6.6ft = 2.012 m$	$hp_b := hp_a$
	$\varphi_a := 23deg$	$\varphi_b := \varphi_a$
	$\varepsilon_a := -9deg$	$\varepsilon_b := \varepsilon_a$
	$h_{w.a} := 1.93ft$	$h_{w.b} := h_{w.a}$

Soil data

$\Phi := 30deg$

$\gamma_1 := 80 \frac{lb}{ft^3} = 1.281 \cdot \frac{tonnes}{m^3}$ $\quad$ $\gamma_2 := 75 \frac{lb}{ft^3} = 0.034 \cdot \frac{tonnes}{ft^3}$

Loading Cases A:

Weight

$$w_{a_1} := B_a \cdot H_a \cdot L_a \cdot \gamma_c = 209.754 \cdot \text{tonnes}$$

Uplift

$$w_{u_1} := B_a \cdot h_{w.a} L_a \cdot \gamma_w = 14.155 \cdot \text{tonnes}$$

Earth Pressure, tonnes

–back

$$\delta := \frac{2}{3}\Phi$$

$$\lambda_{ah} := \frac{(\cos(\Phi))^2}{\left[1 + \sqrt{\frac{(\sin(\Phi + \delta))\sin(\Phi - \varphi_a)}{\cos(\delta) \cdot \cos(\varphi_a)}}\right]^2} = 0.425$$

$$E_{ah_1} := \lambda_{ah} \frac{\left[\gamma_2 \cdot (ha_a)^2 L_a\right]}{2} = 22.598 \cdot \text{tonnes}$$

$$E_{av_1} := E_{ah_1} \tan(\delta) = 8.225 \cdot \text{tonnes}$$

–front

$$\lambda_{ah} := \frac{(\cos(\Phi))^2}{\left[1 + \sqrt{\frac{(\sin(\Phi + \delta))\sin(\Phi - \varepsilon_a)}{\cos(\delta) \cdot \cos(\varepsilon_a)}}\right]^2} = 0.253$$

$$E_{ah_2} := \lambda_{ah} \frac{(hp_a)^2}{2} \cdot L_a \cdot \gamma_2 = 3.472 \cdot \text{tonnes}$$

$$E_{av_2} := E_{ah_2} \cdot \tan(\delta) = 1.264 \cdot \text{tonnes}$$

Calculate resultant loading force

$$\gamma_c := 2.2 \frac{\text{tonnes}}{m^3} = 137.342 \cdot \frac{\text{lb}}{\text{ft}^3} \qquad \gamma_w := 1 \frac{\text{tonnes}}{m^3} = 62.428 \cdot \frac{\text{lb}}{\text{ft}^3}$$

Forces

--Vertical forces

$$R_v := w_{a_1} - w_{u_1} + E_{av_1} + E_{av_2} + P_{a_1} + P_{a_2} - Ta_{sv} = 215.078 \cdot \text{tonnes}$$

Left arm m in the direction of

$$X_{E.ah_1} := \frac{ha_a}{3} = 1.321\,m \qquad Y_{p_1} := \frac{3.5m}{2} = 1.75\,m$$

$$X_{E.av_1} := \frac{B_a}{2} = 2.134\,m \qquad Y_{p_2} := Y_{p_1} = 1.75\,m$$

$$X_{E.ah_2} := \frac{hp_a}{3} = 0.671\,m \qquad Y_{ph} := H_a = 3.962\,m$$

$$X_{E.av_2} := \frac{B_a}{2} = 2.134\,m$$

$$X_{Ta.sh} := H_a - 0.25m = 3.712\,m$$

Moment Mx & My

$$M_x := X_{E.ah_1} \cdot E_{ah_1} + X_{E.ah_2} \cdot E_{ah_2} + X_{E.av_1} \cdot E_{av_1} + X_{E.av_2} \cdot E_{av_2} + Ta_{sh} \cdot X_{Ta.sh} = 79.058 \cdot \text{tonnes} \cdot m$$

$$M_y := P_{a_1} \cdot Y_{p_1} + P_{a_2} \cdot Y_{p_2} + P_{H.a} \cdot Y_{ph} = 25.024 \cdot \text{tonnes} \cdot m$$

Results:

$P_{H.a} = 1.515 \cdot \text{tonnes}$

$E_{ah_1} + E_{ah_2} + Ta_{sh} = 33.246 \cdot \text{tonnes}$

$R_v = 215.078 \cdot \text{tonnes}$

$M_x = 79.058 \cdot \text{tonnes} \cdot m$

$M_y = 25.024 \cdot \text{tonnes} \cdot m$

Check:

$e_x := \frac{M_x}{R_v} = 0.368\,m$ < $\frac{B_a}{6} = 0.711\,m$ o.k.

$e_y := \frac{M_y}{R_v} = 0.116\,m$ < $\frac{L_a}{6} = 0.94\,m$ o.k.

$u := \frac{B_a}{2} - |e_x| = 1.766\,m$ $v := \frac{L_a}{2} - |e_y| = 2.703\,m$

$$\tan\delta_R := \frac{\sqrt{\left(E_{ah_1} + E_{ah_2} + Ta_{sh}\right)^2 + P_{H.a}{}^2}}{R_v} = 0.155$$

$$\delta_R := \operatorname{atan}(0.155) = 8.811 \cdot deg$$

3. Safety against Sliding

$$F_{a.sl} := \frac{\tan(\Phi)}{\tan\delta_R} = 3.731$$

4. Maximum ground bearing pressure

$$\frac{u}{B_a} = 0.414 \qquad \frac{v}{L_a} = 0.479$$

$$Z := 1.3$$

From Table 61,(pg. 211, Krahenbuhl & Wagner)

$$\delta_{max} := Z \cdot \frac{R_v}{4u \cdot v} = 14.643 \cdot \frac{tonnes}{m^2}$$

5. Safety factor against shear failure of ground

$$q := \left(hp_a - h_{w.a}\right) \cdot \gamma_1 + h_{w.a} \cdot \left(\gamma_1 - \gamma_w\right) = 1.99 \cdot \frac{tonnes}{m^2}$$

$$S_q := 1 + \left[0.2 + (\tan(\Phi))^6 \cdot \frac{B_a}{L_a}\right] = 1.228$$

From 6.42 table 21, Krahenbuhl & Wagner

$$S_\gamma := 1 - 0.5\left[0.2 + (\tan(\Phi))^6\right] \cdot \frac{B_a}{L_a} = 0.91$$

$$g_\varepsilon := \left(1 - 0.5\tan\left(-\varepsilon_a\right)\right)^5 = 0.662$$

From 6.42 table 22, Krahenbuhl & Wagner

$$\Phi = 30 \cdot deg \qquad \delta_R = 8.811 \cdot deg$$

$$N_\gamma := 11.5 \qquad N_q := 13.5$$

From 6.42 table 23 α =0, Krahenbuhl & Wagner

$$B_{a'} := 2u = 3.532\,m \qquad L_{a'} := 2v = 5.406\,m$$

$$Q_v := B_{a'} \cdot \left(L_{a'}\right) \cdot \left[\frac{B_{a'}}{2} \cdot \left(\gamma_1 - \gamma_w\right) \cdot N_\gamma \cdot S_\gamma + q \cdot N_q \cdot S_q\right] \cdot g_\varepsilon = 482.72 \cdot tonnes$$

$$F_{a.BC} := \frac{Q_v}{R_v} = 2.244$$

Checked!

6. Reinforcement

NO REQUIREMENTS FOR FOUNDATION WITHOUT FOOT

Loading Cases B:

Weight

$$w_{b_1} := B_b \cdot H_b \cdot L_b \cdot \gamma_c = 209.754 \cdot \text{tonnes}$$

Uplift

$$w_{u_1} := B_b \cdot h_{w.b} L_b \cdot \gamma_w = 14.155 \cdot \text{tonnes}$$

Earth Pressure, tonnes

–back

$$\delta := \frac{2}{3}\Phi$$

$$\lambda_{ah} := \frac{(\cos(\Phi))^2}{\left[1 + \sqrt{\frac{(\sin(\Phi+\delta))\sin(\Phi-\varphi_b)}{\cos(\delta)\cdot\cos(\varphi_b)}}\right]^2} = 0.425$$

$$E_{bh_1} := \lambda_{ah} \frac{\left[\gamma_2 \cdot (ha_b)^2 L_b\right]}{2} = 22.598 \cdot \text{tonnes}$$

$$E_{bv_1} := E_{bh_1} \tan(\delta) = 8.225 \cdot \text{tonnes}$$

–front

$$\lambda_{bh} := \frac{(\cos(\Phi))^2}{\left[1 + \sqrt{\frac{(\sin(\Phi+\delta))\sin(\Phi-\varepsilon_b)}{\cos(\delta)\cdot\cos(\varepsilon_b)}}\right]^2} = 0.253$$

$$E_{bh_2} := \lambda_{bh} \frac{(hp_b)^2}{2} \cdot L_b \cdot \gamma_2 = 3.472 \cdot \text{tonnes}$$

$$E_{bv_2} := E_{bh_2} \cdot \tan(\delta) = 1.264 \cdot \text{tonnes}$$

Forces

--Vertical forces

$$R_v := w_{b_1} - w_{u_1} + E_{bv_1} + E_{bv_2} + P_{b_1} + P_{b_2} - Tb_{sv} = 242.789 \cdot \text{tonnes}$$

Left moment arm in the direction perpendicular to bridge axis

$$X_{E.bh_1} := \frac{ha_b}{3} = 1.321\,m$$

$$X_{E.bv_1} := \frac{B_b}{2} = 2.134\,m$$

$$X_{E.bh_2} := \frac{hp_b}{3} = 0.671\,m$$

$$X_{E.bv_2} := \frac{B_b}{2} = 2.134\,m$$

$$X_{Tb.sh} := H_b - 0.25m = 3.712\,m$$

$$Y_{p_1} := \frac{3.5m}{2} = 1.75\,m$$

$$Y_{p_2} := Y_{p_1} = 1.75\,m$$

$$Y_{ph} := H_b = 3.962\,m$$

Moment Mx & My

$$M_x := X_{E.bh_1} \cdot E_{bh_1} + X_{E.bh_2} \cdot E_{bh_2} + X_{E.bv_1} \cdot E_{bv_1} + X_{E.bv_2} \cdot E_{bv_2} + Tb_{sh} \cdot X_{Tb.sh} = 66.28 \cdot \text{tonnes} \cdot m$$

$$M_y := P_{b_1} \cdot Y_{p_1} + P_{b_2} \cdot Y_{p_2} + P_{H.b} \cdot Y_{ph} = 68.725 \cdot \text{tonnes} \cdot m$$

Results:

$P_{H.b} = 0.538 \cdot \text{tonnes}$

$E_{bh_1} + E_{bh_2} + Tb_{sh} = 29.804 \cdot \text{tonnes}$

$R_v = 242.789 \cdot \text{tonnes}$

$M_x = 66.28 \cdot \text{tonnes} \cdot m$

$M_y = 68.725 \cdot \text{tonnes} \cdot m$

Check:

$e_x := \frac{M_x}{R_v} = 0.273\,m$ < $\frac{B_b}{6} = 0.711\,m$ o.k.

$e_y := \frac{M_y}{R_v} = 0.283\,m$ < $\frac{L_b}{6} = 0.94\,m$ o.k.

$u := \frac{B_b}{2} - |e_x| = 1.861\,m$

$v := \frac{L_b}{2} - |e_y| = 2.536\,m$

$$\tan\delta_R := \frac{\sqrt{\left(E_{bh_1} + E_{bh_2} + Tb_{sh}\right)^2 + P_{H.b}{}^2}}{R_v} = 0.123$$

$$\delta_R := \operatorname{atan}(0.123) = 7.012 \cdot deg$$

3. Safety against Sliding

$$F_{b.sl} := \frac{\tan(\Phi)}{\tan\delta_R} = 4.703$$

4. Maximum ground bearing pressure

$$\frac{u}{B_b} = 0.436 \qquad \frac{v}{L_b} = 0.45$$

From Table 61,pg 211, Krahenbuhl & Wagner

$$Z := 1.32$$

$$\delta_{max} := Z \cdot \frac{R_v}{4u \cdot v} = 16.978 \cdot \frac{tonnes}{m^2}$$

5. Safety factor against shear failure of ground

$$q := \left(hp_b - h_{w.b}\right) \cdot \gamma_1 + h_{w.b} \cdot \left(\gamma_1 - \gamma_w\right) = 1.99 \cdot \frac{tonnes}{m^2}$$

$$S_q := 1 + \left[0.2 + (\tan(\Phi))^6 \cdot \frac{B_b}{L_b}\right] = 1.228$$

From 6.42 table 21, Krahenbuhl & Wagner

$$S_\gamma := 1 - 0.5\left[0.2 + (\tan(\Phi))^6\right] \cdot \frac{B_b}{L_b} = 0.91$$

$$g_\varepsilon := \left(1 - 0.5\tan\left(-\varepsilon_b\right)\right)^5 = 0.662$$

From 6.42 table 22, Krahenbuhl & Wagner

$$\Phi = 30 \cdot deg \qquad \delta_R = 7.012 \cdot deg$$

$$N_\gamma := 12.5 \qquad N_q := 14$$

From 6.42 table 23 α =0, Krahenbuhl & Wagner

$$B_{b'} := 2u = 3.721\,m \qquad L_{b'} := 2v = 5.073\,m$$

$$Q_v := B_{b'} \cdot \left(L_{b'}\right) \cdot \left[\frac{B_{b'}}{2} \cdot \left(\gamma_1 - \gamma_w\right) \cdot N_\gamma \cdot S_\gamma + q \cdot N_q \cdot S_q\right] \cdot g_\varepsilon = 501.913 \cdot tonnes$$

$$F_{b.BC} := \frac{Q_v}{R_v} = 2.067$$

Checked!

6. Reinforcement

NO REQUIREMENTS FOR FOUNDATION WITHOUT FOOT

Check List of Results (North bank):

Loading Cases :

	A	B
Safety Factor against sliding (>1.5)	$F_{a.sl} = 3.731$	$F_{b.sl} = 4.703$
Safety factor against shear failure of soil (>2.0)	$F_{a.BC} = 2.244$	$F_{b.BC} = 2.067$
Eccentricity of resultant force Rv	$\frac{B_{a'}}{2} = 1.766\,m > \frac{B_a}{3} = 1.422\,m$	$\frac{B_{b'}}{2} = 1.861\,m > \frac{B_b}{3} = 1.422\,m$
	$\frac{L_{a'}}{2} = 2.703\,m > \frac{L_a}{3} = 1.88\,m$	$\frac{L_{b'}}{2} = 2.536\,m > \frac{L_b}{3} = 1.88\,m$

$ORIGIN := 1$ $tonnes := 1000kg$

Walkway and Tower foundation

South Bank:

Loads

Loading cases:

A	B
$P_{a_1} := 3.329tonnes$	$P_{b_1} := 17.957tonnes$
$P_{a_2} := 7.54tonnes$	$P_{b_2} := 20.096tonnes$
$P_{H.a} := 1.515tonnes$	$P_{H.b} := 0.538tonnes$
$Ta_{sv} := 0.879tonnes$	$Tb_{sv} := 0.352tonnes$
$Ta_{sh} := 7.175tonnes$	$Tb_{sh} := 3.733tonnes$

Type of foundation

A	B
Without foot in soil (rectangular)	Without foot in soil (rectangular)

Dimensions

A	B
$B_a := 14ft = 4.267\,m$	$B_b := 14ft$
$L_a := 18.5ft = 5.639\,m$	$L_b := 18.5ft$
$H_a := 13ft = 3.962\,m$	$H_b := 13ft$

From topographic survey

A	B
$ha_a := 12.19ft = 3.716\,m$	$ha_b := ha_a$
$hp_a := 8.0ft = 2.438\,m$	$hp_b := hp_a$
$\varphi_a := 16deg$	$\varphi_b := \varphi_a$
$\varepsilon_a := -17deg$	$\varepsilon_b := \varepsilon_a$
$h_{w.a} := 1.93ft$	$h_{w.b} := h_{w.a}$

Soil data

$$\Phi := 30deg$$

$$\gamma_1 := 80\frac{lb}{ft^3} = 1.281 \cdot \frac{tonnes}{m^3} \qquad \gamma_2 := 75\frac{lb}{ft^3} = 0.034 \cdot \frac{tonnes}{ft^3}$$

Calculate resultant loading force

$$\gamma_c := 2.2\frac{tonnes}{m^3} = 137.342 \cdot \frac{lb}{ft^3}$$

$$\gamma_w := 1\frac{tonnes}{m^3} = 62.428 \cdot \frac{lb}{ft^3}$$

Loading Cases A:

Weight

$$w_{a_1} := B_a \cdot H_a \cdot L_a \cdot \gamma_c = 209.754 \cdot \text{tonnes}$$

Uplift

$$w_{u_1} := B_a \cdot h_{w.a} L_a \cdot \gamma_w = 14.155 \cdot \text{tonnes}$$

Earth Pressure, tonnes

–back

$$\delta := \frac{2}{3}\Phi$$

$$\lambda_{ah} := \frac{(\cos(\Phi))^2}{\left[1 + \sqrt{\frac{(\sin(\Phi + \delta))\sin(\Phi - \varphi_a)}{\cos(\delta) \cdot \cos(\varphi_a)}}\right]^2} = 0.355$$

$$E_{ah_1} := \lambda_{ah} \frac{\left[\gamma_2 \cdot (ha_a)^2 L_a\right]}{2} = 16.613 \cdot \text{tonnes}$$

$$E_{av_1} := E_{ah_1} \tan(\delta) = 6.046 \cdot \text{tonnes}$$

–front

$$\lambda_{ah} := \frac{(\cos(\Phi))^2}{\left[1 + \sqrt{\frac{(\sin(\Phi + \delta))\sin(\Phi - \varepsilon_a)}{\cos(\delta) \cdot \cos(\varepsilon_a)}}\right]^2} = 0.234$$

$$E_{ah_2} := \lambda_{ah} \frac{(hp_a)^2}{2} \cdot L_a \cdot \gamma_2 = 4.716 \cdot \text{tonnes}$$

$$E_{av_2} := E_{ah_2} \cdot \tan(\delta) = 1.717 \cdot \text{tonnes}$$

Forces

--Vertical forces

$$R_v := w_{a_1} - w_{u_1} + E_{av_1} + E_{av_2} + P_{a_1} + P_{a_2} - Ta_{sv} = 213.353 \cdot \text{tonnes}$$

Left moment arm in the direction perpendicular to the bridge axis

$$X_{E.ah_1} := \frac{ha_a}{3} = 1.239\,m$$

$$X_{E.av_1} := \frac{B_a}{2} = 2.134\,m$$

$$X_{E.ah_2} := \frac{hp_a}{3} = 0.813\,m$$

$$X_{E.av_2} := \frac{B_a}{2} = 2.134\,m$$

$$X_{Ta.sh} := H_a - 0.25m = 3.712\,m$$

$$Y_{p_1} := \frac{3.5m}{2} = 1.75\,m$$

$$Y_{p_2} := Y_{p_1} = 1.75\,m$$

$$Y_{ph} := H_a = 3.962\,m$$

Moment Mx & My

$$M_x := X_{E.ah_1} \cdot E_{ah_1} + X_{E.ah_2} \cdot E_{ah_2} + X_{E.av_1} \cdot E_{av_1} + X_{E.av_2} \cdot E_{av_2} + Ta_{sh} \cdot X_{Ta.sh} = 67.608 \cdot \text{tonnes} \cdot m$$

$$M_y := P_{a_1} \cdot Y_{p_1} + P_{a_2} \cdot Y_{p_2} + P_{H.a} \cdot Y_{ph} = 25.024 \cdot \text{tonnes} \cdot m$$

Results:

$$P_{H.a} = 1.515 \cdot \text{tonnes}$$

$$E_{ah_1} + E_{ah_2} + Ta_{sh} = 28.504 \cdot \text{tonnes}$$

$$R_v = 213.353 \cdot \text{tonnes}$$

$$M_x = 67.608 \cdot \text{tonnes} \cdot m$$

$$M_y = 25.024 \cdot \text{tonnes} \cdot m$$

Check:

$$e_x := \frac{M_x}{R_v} = 0.317\,m \quad < \quad \frac{B_a}{6} = 0.711\,m \quad \text{o.k.}$$

$$e_y := \frac{M_y}{R_v} = 0.117\,m \quad < \quad \frac{L_a}{6} = 0.94\,m \quad \text{o.k.}$$

$$u := \frac{B_a}{2} - |e_x| = 1.817\,m \qquad v := \frac{L_a}{2} - |e_y| = 2.702\,m$$

$$\tan\delta_R := \frac{\sqrt{\left(E_{ah_1} + E_{ah_2} + Ta_{sh}\right)^2 + P_{H.a}{}^2}}{R_v} = 0.134$$

$$\delta_R := \text{atan}(0.134) = 7.632 \cdot \text{deg}$$

3. Safety against Sliding

$$F_{a.sl} := \frac{\tan(\Phi)}{\tan\delta_R} = 4.315$$

4. Maximum ground bearing pressure

$$\frac{u}{B_a} = 0.426 \qquad \frac{v}{L_a} = 0.479$$

From Table 61,pg 211, Krahenbuhl & Wagner. $Z := 1.29$

$$\delta_{max} := Z \cdot \frac{R_v}{4u \cdot v} = 14.016 \cdot \frac{\text{tonnes}}{m^2}$$

5. Safety factor against shear failure of ground

$$q := \left(hp_a - h_{w.a}\right) \cdot \gamma_1 + h_{w.a} \cdot \left(\gamma_1 - \gamma_w\right) = 2.536 \cdot \frac{\text{tonnes}}{m^2}$$

$$S_q := 1 + \left[0.2 + (\tan(\Phi))^6 \cdot \frac{B_a}{L_a}\right] = 1.228$$

From 6.42 table 21, Krahenbuhl & Wagner

$$S_\gamma := 1 - 0.5\left[0.2 + (\tan(\Phi))^6\right] \cdot \frac{B_a}{L_a} = 0.91$$

$$g_\varepsilon := \left(1 - 0.5\tan\left(-\varepsilon_a\right)\right)^5 = 0.436$$

From 6.42 table 22, Krahenbuhl & Wagner

$$\Phi = 30 \cdot \text{deg} \qquad \delta_R = 7.632 \cdot \text{deg}$$

$$N_\gamma := 12 \qquad N_q := 14.2$$

From 6.42 table 23 α =0, Krahenbuhl & Wagner

$$B_{a'} := 2u = 3.633\,\text{m} \qquad L_{a'} := 2v = 5.404\,\text{m}$$

$$Q_v := B_{a'} \cdot \left(L_{a'}\right) \cdot \left[\frac{B_{a'}}{2} \cdot \left(\gamma_1 - \gamma_w\right) \cdot N_\gamma \cdot S_\gamma + q \cdot N_q \cdot S_q\right] \cdot g_\varepsilon = 426.769 \cdot \text{tonnes}$$

$$F_{a.BC} := \frac{Q_v}{R_v} = 2$$

Checked!

6. Reinforcement

NO REQUIREMENTS FOR FOUNDATION WITHOUT FOOT

Loading Cases B:

Weight

$$w_{b_1} := B_b \cdot H_b \cdot L_b \cdot \gamma_c = 209.754 \cdot \text{tonnes}$$

Uplift

$$w_{u_1} := B_b \cdot h_{w.b} L_b \cdot \gamma_w = 14.155 \cdot \text{tonnes}$$

Earth Pressure, tonnes

–back

$$\delta := \frac{2}{3}\Phi$$

$$\lambda_{ah} := \frac{(\cos(\Phi))^2}{\left[1 + \sqrt{\frac{(\sin(\Phi+\delta))\sin(\Phi-\varphi_b)}{\cos(\delta)\cdot\cos(\varphi_b)}}\right]^2} = 0.355$$

$$E_{bh_1} := \lambda_{ah} \frac{\left[\gamma_2 \cdot (ha_b)^2 L_b\right]}{2} = 16.613 \cdot \text{tonnes}$$

$$E_{bv_1} := E_{bh_1} \tan(\delta) = 6.046 \cdot \text{tonnes}$$

–front

$$\lambda_{bh} := \frac{(\cos(\Phi))^2}{\left[1 + \sqrt{\frac{(\sin(\Phi+\delta))\sin(\Phi-\varepsilon_b)}{\cos(\delta)\cdot\cos(\varepsilon_b)}}\right]^2} = 0.234$$

$$E_{bh_2} := \lambda_{bh} \frac{(hp_b)^2}{2} \cdot L_b \cdot \gamma_2 = 4.716 \cdot \text{tonnes}$$

$$E_{bv_2} := E_{bh_2} \cdot \tan(\delta) = 1.717 \cdot \text{tonnes}$$

Forces

--Vertical forces

$$R_v := w_{b_1} - w_{u_1} + E_{bv_1} + E_{bv_2} + P_{b_1} + P_{b_2} - Tb_{sv} = 241.064 \cdot \text{tonnes}$$

Left moment arm the direction perpendicular to the bridge axis

$$X_{E.bh_1} := \frac{ha_b}{3} = 1.239\,m$$

$$X_{E.bv_1} := \frac{B_b}{2} = 2.134\,m$$

$$X_{E.bh_2} := \frac{hp_b}{3} = 0.813\,m$$

$$X_{E.bv_2} := \frac{B_b}{2} = 2.134\,m$$

$$X_{Tb.sh} := H_b - 0.25m = 3.712\,m$$

$$Y_{p_1} := \frac{3.5m}{2} = 1.75\,m$$

$$Y_{p_2} := Y_{p_1} = 1.75\,m$$

$$Y_{ph} := H_b = 3.962\,m$$

Moment Mx & My

$$M_x := X_{E.bh_1} \cdot E_{bh_1} + X_{E.bh_2} \cdot E_{bh_2} + X_{E.bv_1} \cdot E_{bv_1} + X_{E.bv_2} \cdot E_{bv_2} + Tb_{sh} \cdot X_{Tb.sh} = 54.83 \cdot \text{tonnes} \cdot m$$

$$M_y := P_{b_1} \cdot Y_{p_1} + P_{b_2} \cdot Y_{p_2} + P_{H.b} \cdot Y_{ph} = 68.725 \cdot \text{tonnes} \cdot m$$

Results:

$$P_{H.b} = 0.538 \cdot \text{tonnes}$$

$$E_{bh_1} + E_{bh_2} + Tb_{sh} = 25.062 \cdot \text{tonnes}$$

$$R_v = 241.064 \cdot \text{tonnes}$$

$$M_x = 54.83 \cdot \text{tonnes} \cdot m$$

$$M_y = 68.725 \cdot \text{tonnes} \cdot m$$

Check:

$$e_x := \frac{M_x}{R_v} = 0.227\,m \quad < \quad \frac{B_b}{6} = 0.711\,m \quad \text{o.k.}$$

$$e_y := \frac{M_y}{R_v} = 0.285\,m \quad < \quad \frac{L_b}{6} = 0.94\,m \quad \text{o.k.}$$

$$u := \frac{B_b}{2} - |e_x| = 1.906\,m \qquad v := \frac{L_b}{2} - |e_y| = 2.534\,m$$

$$\tan\delta_R := \frac{\sqrt{\left(E_{bh_1} + E_{bh_2} + Tb_{sh}\right)^2 + P_{H.b}{}^2}}{R_v} = 0.104$$

$$\delta_R := \operatorname{atan}(0.104) = 5.937 \cdot deg$$

3. Safety against Sliding

$$F_{b.sl} := \frac{\tan(\Phi)}{\tan\delta_R} = 5.552$$

4. Maximum ground bearing pressure

$$\frac{u}{B_b} = 0.447 \qquad \frac{v}{L_b} = 0.449$$

From Table 61,pg 211, Krahenbuhl & Wagner $Z := 1.30$

$$\delta_{max} := Z \cdot \frac{R_v}{4u \cdot v} = 16.218 \cdot \frac{tonnes}{m^2}$$

5. Safety factor against shear failure of ground

$$q := \left(hp_b - h_{w.b}\right) \cdot \gamma_1 + h_{w.b} \cdot \left(\gamma_1 - \gamma_w\right) = 2.536 \cdot \frac{tonnes}{m^2}$$

$$S_q := 1 + \left[0.2 + (\tan(\Phi))^6 \cdot \frac{B_b}{L_b}\right] = 1.228$$

From 6.42 table 21, Krahenbuhl & Wagner

$$S_\gamma := 1 - 0.5\left[0.2 + (\tan(\Phi))^6\right] \cdot \frac{B_b}{L_b} = 0.91$$

$$g_\varepsilon := \left(1 - 0.5\tan\left(-\varepsilon_b\right)\right)^5 = 0.436$$

From 6.42 table 22, Krahenbuhl & Wagner

$$\Phi = 30 \cdot deg \qquad \delta_R = 5.937 \cdot deg$$

$$N_\gamma := 13.5 \qquad N_q := 15$$

From 6.42 table 23 α =0, Krahenbuhl & Wagner

$$B_{b'} := 2u = 3.812\,m \qquad L_{b'} := 2v = 5.069\,m$$

$$Q_v := B_{b'} \cdot \left(L_{b'}\right) \cdot \left[\frac{B_{b'}}{2} \cdot \left(\gamma_1 - \gamma_w\right) \cdot N_\gamma \cdot S_\gamma + q \cdot N_q \cdot S_q\right] \cdot g_\varepsilon = 449.473 \cdot tonnes$$

$$F_{b.BC} := \frac{Q_v}{R_v} = 1.865$$

6. Reinforcement

NO REQUIREMENTS FOR FOUNDATION WITHOUT FOOT

Check List of Results (South bank):

Loading Cases : A B

	A	B
Safety Factor against sliding (>1.5)	$F_{a.sl} = 4.315$	$F_{b.sl} = 5.552$
Safety factor against shear failure of ground (>2.0)	$F_{a.BC} = 2$	$F_{b.BC} = 1.865$

Eccentricity of resultant force Rv

$$\frac{B_{a'}}{2} = 1.817\,m \quad > \quad \frac{B_a}{3} = 1.422\,m \qquad \frac{B_{b'}}{2} = 1.906\,m \quad > \quad \frac{B_b}{3} = 1.422\,m$$

$$\frac{L_{a'}}{2} = 2.702\,m \quad > \quad \frac{L_a}{3} = 1.88\,m \qquad \frac{L_{b'}}{2} = 2.534\,m \quad > \quad \frac{L_b}{3} = 1.88\,m$$

SYMBOLS

LL	Liquid Limit
C_c	Compression index
e	void ratio
C_v	Coefficient if consolidation
γ_c	Unit weight of Concrete
γ_{soil}	Unit weight of Soil
V_{block}	Volume of the foundation
P_{tower}	Vertical load excluding of foundation block acting on the bottom of the foundation block
P_i	Total Load corresponding to soil self-weight
P_f	Total load of Tower plus foundation
Δ_H	Total settlement
$T_{50.90}$	Constants of formula for time rate of settlement
$t_{50.90}$	time rate of settlement of 50% and 90% of total settlement

Foundation Settlement

$ORIGIN := 1$

$tonnes := 1000kg$ $\qquad$ $year := 365day$

Initial Data

$LL := 28$ (Silty Clay) $\qquad$ $Cc := 0.009(LL - 10) = 0.162$

$e_i := 0.75$ (Loose silty clay soil) $\qquad$ $C_v := 0.03\frac{ft^2}{day}$ (Assumed for Silty Clay)

$\gamma_c := 150\frac{lb}{ft^3}$ $\qquad$ $H := 13ft$ (worst scenario)

$\gamma_{soil} := 75\frac{lb}{ft^3}$ $\qquad$ $H_{dr} := H$ (Singlely drained layer)

$V_{block} := 14ft \cdot 18.5ft \cdot 13ft = 3.367 \times 10^3 \cdot ft^3$

$P_{tower} := 20.096tonnes = 4.43 \times 10^4 \cdot lb$

(Use Wind/3 +Full load (Load case B) of Tower calculations.--worst scenario)

$P_i := \gamma_{soil} \cdot H = 975 \cdot \frac{lb}{ft^2}$

$P_f := \frac{\left(P_{tower} + \gamma_c \cdot V_{block}\right)}{14ft \cdot 18.5ft} = 2.121 \times 10^3 \cdot \frac{lb}{ft^2}$

Total Settlement

$\Delta H := H \cdot \frac{Cc}{1 + e_i} \cdot \log\left(\frac{P_f}{P_i}\right) = 0.406 \cdot ft$ $\qquad$ (Total settelment)

Time rate of settlement

50% of total settlement

$T_{50} := 0.197$ (Table 1.2 of GE handout)

$t_{50} := T_{50} \cdot \frac{H_{dr}^2}{C_v} = 3.04 \cdot year$

90% of total settlement

$T_{90} := 0.848$

$t_{90} := T_{90} \cdot \frac{H_{dr}^2}{C_v} = 13.088 \cdot year$

Walkway Timber Checks (NDS-05 Code, LRFD)

$ORIGIN := 1$

Member Information:

Wood Loads:

MC: Moisture content in %

G: Specific Gravity as to NDS (Assuming Southern Pin)

D_{wood}: Density of Wood in pcf

$G := 0.55 \qquad P_L := 100 \frac{lb}{ft^2}$

$MC := 25$

$$D_{wood} := 62.4 \cdot \left[\frac{G}{1 + G \cdot (0.009)(MC)}\right]\left(1 + \frac{MC}{100}\right) = 38.176$$

$$D_{wood} := 1.2 \frac{D_{wood} \cdot lb}{ft^3} = 45.811 \cdot \frac{lb}{ft^3}$$

$$Live_{load} := 1.6 \cdot P_L = 160 \cdot \frac{lb}{ft^2}$$

PLANKING CALCULATIONS: Using 2x6 Boards

$b := 5.5in \qquad d := 1.5in$

$Deck_{width} := 3.9368ft = 1.2\,m$

$L_p := 2.3662ft = 0.721\,m$

$A_p := b \cdot d = 0.057 \cdot ft^2$

$$W_p := D_{wood} \cdot A_p + Live_{load} \cdot Deck_{width} = 632.513 \cdot \frac{lb}{ft}$$

The distributed weight acting on the planking is **632.5 lbs/ft,** which acts on a single plank.

$$M_p := \frac{W_p \cdot L_p^2}{8} = 442.672 \cdot lb \cdot ft$$

$$I := \frac{Deck_{width} \cdot d^3}{12} = 13.287 \cdot in^4$$

$c := \frac{d}{2} \qquad S_p := \frac{I}{c}$

$$f_b := \frac{M_p}{S_p} = 299.852 \cdot \frac{lb}{in^2}$$

Design Values: (*NDS-S Table 4B (2"-4" thick/ 5"-6" wide):* ***No.1)***

$F_b := 1650 \frac{lb}{in^2}$ $F_v := 175 \frac{lb}{in^2}$ $E := 1700000 \frac{lb}{in^2}$

Adjustment Factors

(NDS Table 4.3.1)

Beam stability Factor, CL

$C_L := 1.0$ < NDS 3.3.3.1

Repetitive Member Factor, Cr

$C_r := 1.15$ NDS-S Table 4B

Size Factor, CF

$C_F := 1.0$ NDS-S Table 4B

Wet Service Factor, Cm (since Moisture content is assumed greater than 19%)

$F_b \cdot C_F = 1.65 \times 10^3 \cdot \frac{lb}{in^2}$ > 1150 psi

$C_M := 0.85$ NDS-S Table 4B

Resistance Factor

$\phi_b := 0.85$ $\phi_v := 0.75$ NDS,Appendix-Table N2

Format Conversion Factors, K.F_fb

$K_{F\_Fb} := \frac{2.16}{\phi_b}$ $K_{F\_Fv} := \frac{2.16}{\phi_v}$ NDS,Appendix-Table N1

Time effect factor, λ

$\lambda := 0.8$ NDS,Appendix-Table N3

Temperature Factor

$C_t := 1.0$ NDS Table 2.3.3 (Assume T<100 F)

Incising factor Ci

$C_i := 1.0$ NDS 4.3.8

Bending Check:

$$F'b := \lambda \cdot K_{F\_Fb} \cdot \phi_b \cdot F_b \cdot C_M \cdot C_t \cdot C_r \cdot C_F$$

$F'b = 2.787 \times 10^3 \cdot \frac{lb}{in^2}$ > $f_b = 299.852 \cdot \frac{lb}{in^2}$ OK in bending

Shear Check:

$$F'v := \lambda \cdot K_{F\_Fv} \cdot \phi_v \cdot F_v \cdot C_M \cdot C_t \cdot C_i$$

$$F'v = 257.04 \cdot \frac{lb}{in^2}$$

$$V_{load} := \frac{W_p \cdot L_p}{2} = 748.326 \cdot lb$$

$Notch_{max} := \frac{1}{4} \cdot b = 1.375 \cdot in$ *(NDS 4.3.3.1: Notch max = 1/4 of the depth)*

$$Notch := 1.0in$$

$$Depth_{notch} := b - Notch = 4.5 \cdot in$$

$$d_n := Depth_{notch}$$

$$V'r := \left(\frac{2}{3}\right) \cdot F'v \cdot d \cdot d_n \cdot \left(\frac{d_n}{b}\right)^2 = 774.306 \cdot lb$$

$V_{load} = 748.326 \cdot lb$ < $V'r = 774.306 \cdot lb$ OK in shear at the notch

Check Deflection

Assume $\Delta_{max} := \frac{L_p}{360} = 0.079 \cdot in$

Unfactored live load : $P := \frac{Live_{load} \cdot Deck_{width}}{1.6} = 32.807 \cdot \frac{lb}{in}$

$\Delta := \frac{5 \cdot (P) \cdot L_p^{\ 4}}{384 \cdot E \cdot I} = 0.012 \cdot in$ < $\Delta_{max} = 0.079 \cdot in$ OK in Maximum Deflection

APPENDIX H: ANCHORAGE DESIGN CALCULATIONS

H_1, H_2, B, L = Dimensions of the structures.

h_a, φ = Height and inclination of backfilling soil $\varphi \le \Phi_2$

h_p, ε = Height and inclination of ground surface in front of a structure

h_w = Distance of the ground- water level from the anchorage base level at the front of the structure.

$\gamma, \gamma_1, \gamma_2$ = Unit weight of moist soil.

$\gamma_1 :=$ subsoil $\gamma_2 :=$ backfilling

Φ, Φ_1, Φ_2 = Angle of internal friction of soil.

$\Phi_1 :=$ subsoil $\Phi_2 :=$ backfilling

γ_c = Unit weight of concrete/ masonry. $\gamma_c := 150 \frac{lb}{ft^3}$

γ_w = Unit weight of water. $\gamma_w := 62.428 \frac{lb}{ft^3}$

δ_R = Inclination of the resultant force towards vertical.

$\frac{B}{2}$ = Distance of the resultant force towards vertical.

w_1, w_2, w_3 = Partial weights of the anchorage block.

δ = Angle of wall friction. $\delta := \frac{2}{3}\Phi$

P_w = Water pressure.

M_F = Sum of static moments of the acting forces in point F.

F_{SL} = Safety factor against sliding.

F_{BC} = Safety factor against shear failure of ground.

N_γ, N_q = Ground bearing - capacity coefficients.

s_γ, s_q = Shape correcting coefficients

g_ε = Topographical correcting coefficients

$ORIGIN := 1$

North bank

Initial Layout data

Cable tension: $T := 43.969ton$

Cable inclination: $\beta := 25.641deg$

Additional load on the top of block: $A := 0$

$a := 0$

Soil Data from survey: $\Phi := 30deg$

$\gamma_2 := 80\frac{lb}{ft^3}$

$\gamma_1 := 75\frac{lb}{ft^3}$

Block dimensions: $B := 14.5ft = 4.42\,m$

$L := 16ft$

$H_1 := 10ft$

$H_2 := 4ft$

$b := 0$

Topographical conditions: $h_a := H_1 + 1.75ft$

$h_w := 0$

$\varphi := 8deg$

$\varepsilon := 8deg$

Other data $\gamma_w := 1000\frac{kg}{m^3} = 62.428\cdot\frac{lb}{ft^3}$

$\gamma_c := 150\frac{lb}{ft^3}$

$\delta := \frac{2}{3}\Phi$

$h_p := H_2$

Calculation

Volume of Block

$$V_1 := \frac{H_1 + 0.1m + H_2 + 1.0m}{2} \cdot B \cdot L = 5.784 \times 10^4 L$$

$$V_2 := b \cdot 1.0m \cdot L = 0$$

$$V_3 := \frac{1}{2} \cdot 0.5m \cdot 1.0m \cdot L = 1.219 \times 10^3 L$$

$$V_4 := \frac{1}{2} \cdot 1.0m \cdot (B - 1.0m) \cdot L = 8.338 \times 10^3 L$$

$$V := V_1 - V_2 - V_3 - V_4 = 1.705 \times 10^3 \cdot ft^3$$

Bottom inclination:

$$\tan(\alpha) := \frac{H_1 + 0.1m - 1.0m - H_2}{B}$$

$$\alpha := \operatorname{atan}\left(\frac{H_1 + 0.1m - 1.0m - H_2}{B}\right) = 11.868 \cdot deg$$

Dead weight W and moment in point F:

$$W := \gamma_c \cdot V = 2.558 \times 10^5 \cdot lb$$

Moment :

$$w_1 := \frac{B}{3} \cdot \frac{2 \cdot (H_1 + 0.1m) + (H_2 + 1.0m)}{(H_1 + 0.1m) + (H_2 + 1.0m)}$$

$$w_2 := \frac{b}{2}$$

$$w_3 := b + \frac{1}{3} \cdot 0.5m$$

$$w_4 := 1.0m + \frac{2}{3} \cdot (B - 1.0m)$$

$$M_{Fw} := \gamma_c \cdot (V_1 \cdot w_1 - V_2 \cdot w_2 - V_3 \cdot w_3 - V_4 \cdot w_4) = 1.871 \times 10^6 \cdot lb \cdot ft$$

Load due to coble tension:

$$T_V := T \cdot \sin(\beta) = 3.805 \times 10^4 \cdot lb$$

$$T_H := T \cdot \cos(\beta) = 7.928 \times 10^4 \cdot lb$$

Active earth pressure:

$$\lambda_{ah} := \frac{(\cos(\Phi))^2}{\left[1 + \sqrt{\frac{(\sin(\Phi+\delta))\sin(\Phi-\varphi)}{\cos(\delta)\cdot\cos(\varphi)}}\right]^2} = 0.31$$

$$E_{ah} := \lambda_{ah}\frac{\left[\gamma_2\cdot\left(h_a\right)^2 L\right]}{2} = 2.74\times10^4\cdot lb$$

$$E_{av} := E_{ah}\tan(\delta) = 5.757\times10^3\cdot lb$$

Resultant loading force:

$$R_V := W + E_{av} - T_V = 2.235\times10^5\cdot lb$$

$$R_H := E_{ah} + T_H = 1.067\times10^5\cdot lb$$

Static moment in point F:

$$M_F := M_{Fw} + E_{av}\cdot B - T_V\cdot b - T_H\cdot\left(H_2 + 0.2m\right) - E_{ah}\cdot\left(\frac{h_a}{3} - B\cdot\tan(\alpha)\right) = 1.561\times10^6\cdot lb\cdot ft$$

$$\delta_R := \operatorname{atan}\left(\frac{R_H}{R_V}\right) = 25.517\cdot deg$$

$$B := \frac{2M_F}{R_V + R_H\cdot\tan(\alpha)} = 12.699\cdot ft \qquad \frac{B}{2} = 6.349\cdot ft$$

Security against sliding

$$\sin(\Phi) = 0.5$$

$$T\Phi := \frac{\sin(\Phi)}{\cos(\Phi)} = 0.577$$

$$\cos(\Phi) = 0.866$$

$$\sin\left(\delta_R - \alpha\right) = 0.236$$

$$T\delta := \frac{\sin\left(\delta_R - \alpha\right)}{\cos\left(\delta_R - \alpha\right)} = 0.243$$

$$\cos\left(\delta_R - \alpha\right) = 0.972$$

$$F_{SL} := \frac{T\Phi}{T\delta} = 2.378$$

$$F_{SL} > req\_F_{SL} = \blacksquare\cdot 2.0$$

Check !

Security against soil failure

$$q := h_p \cdot \gamma_1 = 300 \cdot \frac{lb}{ft^2}$$

$$s_\gamma := 1 - 0.5 \cdot \left[\left(0.2 + \tan(\Phi)^6\right) \cdot \frac{B}{L} \right] = 0.909$$

$$s_q := 1 + \left[0.2 \cdot (\tan(\Phi))^6 \cdot \frac{B}{L} \right] = 1$$

$$g_\varepsilon := (1 - 0.5 \tan(\varepsilon))^5 = 0.574$$

From table

$N_q := 8$ $\quad$ $N_\gamma := 5.2$

$$F_{BC} := \frac{B \cdot L}{R_V} \cdot \left(\frac{B}{2} \cdot \gamma_1 \cdot N_\gamma \cdot s_\gamma + q \cdot N_q \cdot s_q \right) \cdot g_\varepsilon = 2.428$$

$F_{BC} > req\_F_{BC} = \blacksquare \cdot 1.5$ $\quad$ **Check !**

$ORIGIN := 1$

South Bank

Initial Layout data

Cable tension: $T := 43.969ton$

Cable inclination: $\beta := 25.641deg$

Additional load on the top of block: $A := 0$

$a := 0$

Soil Data from survey: $\Phi := 30deg$

$\gamma_2 := 80\frac{lb}{ft^3}$

$\gamma_1 := 75\frac{lb}{ft^3}$

Block dimensions: $B := 14.5ft$

$L := 16ft$

$H_1 := 10ft$

$H_2 := 4ft$

$b := 0$

Topographical conditions: $h_a := H_1 + 2ft$

$h_w := 0$

$\varphi := 16deg$

$\varepsilon := 16deg$

Other data $\gamma_w := 1000\frac{kg}{m^3}$

$\gamma_c := 150\frac{lb}{ft^3}$

$\delta := \frac{2}{3}\Phi$

$h_p := H_2$

Calculation

Volume of Block

$$V_1 := \frac{H_1 + 0.1m + H_2 + 1.0m}{2} \cdot B \cdot L = 5.784 \times 10^4 L$$

$$V_2 := b \cdot 1.0m \cdot L = 0$$

$$V_3 := \frac{1}{2} \cdot 0.5m \cdot 1.0m \cdot L = 1.219 \times 10^3 L$$

$$V_4 := \frac{1}{2} \cdot 1.0m \cdot (B - 1.0m) \cdot L = 8.338 \times 10^3 L$$

$$V := V_1 - V_2 - V_3 - V_4 = 1.705 \times 10^3 \cdot ft^3$$

Bottom inclination:

$$\tan(\alpha) := \frac{H_1 + 0.1m - 1.0m - H_2}{B}$$

$$\alpha := \operatorname{atan}\left(\frac{H_1 + 0.1m - 1.0m - H_2}{B}\right) = 11.868 \cdot deg$$

Dead weight W and moment in point F:

$$W := \gamma_c \cdot V = 2.558 \times 10^5 \cdot lb$$

Moment :

$$w_1 := \frac{B}{3} \cdot \frac{2 \cdot (H_1 + 0.1m) + (H_2 + 1.0m)}{(H_1 + 0.1m) + (H_2 + 1.0m)}$$

$$w_2 := \frac{b}{2}$$

$$w_3 := b + \frac{1}{3} \cdot 0.5m$$

$$w_4 := 1.0m + \frac{2}{3} \cdot (B - 1.0m)$$

$$M_{Fw} := \gamma_c \cdot (V_1 \cdot w_1 - V_2 \cdot w_2 - V_3 \cdot w_3 - V_4 \cdot w_4) = 1.871 \times 10^6 \cdot lb \cdot ft$$

Load due to coble tension:

$$T_V := T \cdot \sin(\beta) = 3.805 \times 10^4 \cdot lb$$

$$T_H := T \cdot \cos(\beta) = 7.928 \times 10^4 \cdot lb$$

Active earth pressure:

$$\lambda_{ah} := \frac{(\cos(\Phi))^2}{\left[1 + \sqrt{\frac{(\sin(\Phi+\delta))\sin(\Phi-\varphi)}{\cos(\delta)\cdot\cos(\varphi)}}\right]^2} = 0.355$$

$$E_{ah} := \lambda_{ah}\frac{\left[\gamma_2\cdot(h_a)^2 L\right]}{2} = 3.274\times 10^4\cdot lb$$

$$E_{av} := E_{ah}\tan(\delta) = 6.881\times 10^3\cdot lb$$

Resultant loading force:

$$R_V := W + E_{av} - T_V = 2.246\times 10^5\cdot lb$$

$$R_H := E_{ah} + T_H = 1.12\times 10^5\cdot lb$$

Static moment in point F:

$$M_F := M_{Fw} + E_{av}\cdot B - T_V\cdot b - T_H\cdot(H_2 + 0.2m) - E_{ah}\cdot\left(\frac{h_a}{3} - B\cdot\tan(\alpha)\right) = 1.57\times 10^6\cdot lb\cdot ft$$

$$\delta_R := \operatorname{atan}\left(\frac{R_H}{R_V}\right) = 26.508\cdot deg$$

$$B := \frac{2M_F}{R_V + R_H\cdot\tan(\alpha)} = 12.655\cdot ft \qquad \frac{B}{2} = 6.328\cdot ft$$

Security against sliding

$\sin(\Phi) = 0.5$

$\cos(\Phi) = 0.866$

$$T\Phi := \frac{\sin(\Phi)}{\cos(\Phi)} = 0.577$$

$\sin(\delta_R - \alpha) = 0.253$

$\cos(\delta_R - \alpha) = 0.968$

$$T\delta := \frac{\sin(\delta_R - \alpha)}{\cos(\delta_R - \alpha)} = 0.261$$

$$F_{SL} := \frac{T\Phi}{T\delta} = 2.21$$

$F_{SL} > req\_F_{SL}=2.0$

Check !

Security against soil failure

$$q := h_p \cdot \gamma_1 = 300 \cdot \frac{lb}{ft^2}$$

$$s_\gamma := 1 - 0.5 \cdot \left[\left(0.2 + \tan(\Phi)^6\right) \cdot \frac{B}{L}\right] = 0.909$$

$$s_q := 1 + \left[0.2 \cdot (\tan(\Phi))^6 \cdot \frac{B}{L}\right] = 1$$

$$g_\varepsilon := (1 - 0.5\tan(\varepsilon))^5 = 0.574$$

From table

$N_q := 8$ $N_\gamma := 5.2$

$$F_{BC} := \frac{B \cdot L}{R_V} \cdot \left(\frac{B}{2} \cdot \gamma_1 \cdot N_\gamma \cdot s_\gamma + q \cdot N_q \cdot s_q\right) \cdot g_\varepsilon = 2.403$$

$F_{BC} > req\_F_{BC}$=1.5

Check !

APPENDIX I: SUSPENDER DESIGN CALCULATIONS

SYMBOLS

l	Bridge Span, distance between tower axes
d_i	Distance from center of main cables to center of spanning cables for suspender No.i
f	Sag, vertical distance from tower saddle to the lowest point of the main cable
h_t	Tower height, vertical distance between top of walkway and tower foundation and saddle cable
n	Running suspender numbers
l_{sus}	Total suspender length for suspender No. i
ls	Length of standard piece
lr	length extra piece
lsc	Cutting length of standard piece
lrc	Cutting length of extra piece
j_i	Required number of standard pieces for suspender No.i
n_{max}	Maximum n
N	Total suspender length numbers
x_i	Distance of suspender No.i from the bridge center
c, k	Constants in the formula for di
e	Euler constant
W	Total weight of suspender rods
S	Total surface area of suspender rods

Suspenders

$ORIGIN := 1$

$tonnes := 1000kg$

Initial data

$l := 56.69m = 185.991 \cdot ft$

$h_t := 9.2m = 30.184 \cdot ft$

$f_d := 6.449m = 21.158 \cdot ft$

Center distance of cables

$$\frac{l - 4.6m}{2.4m} + 1 = 22.704$$

$n_{max} := 23$ $\quad$ $i := 1..23$

$$n := \begin{pmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 22 \\ 23 \end{pmatrix}$$

$$c := \frac{8f_d}{l^2} = 0.016\frac{1}{m}$$

$$e = 2.718$$

$$k := \frac{2\cdot c\cdot f_d}{e^{\left(\frac{c\cdot l}{2}\right)} + e^{\left(\frac{-c\cdot l}{2}\right)} - 2} = 0.983$$

$$\frac{k}{2c} = 30.614\,m$$

$$x_i := \left(n_i - 1\right)\cdot 1.2m$$

$$d_i := \frac{k}{2\cdot c}\left(e^{c\cdot x_i} + e^{-c\cdot x_i} - 2\right) + \frac{4\cdot\left(x_i\right)^2}{l^2}\left(h_t - f_d - 1.05m\right) + 1.05m$$

Total suspender length:

$$lsus_i := d_i - 0.542m$$

Number j of standard pieces with standard length ls =1650 mm / lsc =1830mm

$$j_i := \mathrm{trunc}\left(\frac{lsus_i - 0.35m}{1.65m}\right)$$

$$l_{r_i} := d_i - 0.542m - j_i\cdot 1.65m$$

$$l_{rc_i} := l_{r_i} + 0.18m$$

$$w_{n_i} := j_i\cdot 1.625kg + l_{rc_i}\cdot 0.888\frac{kg}{m}$$

$$S_{n_i} := j_i\cdot 0.069m^2 + l_{rc_i}\cdot 0.0377m$$

Summary:

Total Suspenders numbers:

$$N := 4 \cdot n_{max} - 2 = 90$$

Total Weight of Suspender rods

$$W := 4 \cdot \sum_{i=1}^{n_{max}} w_{n_i} - 2 w_{n_1} = 266.65\,kg$$

$$W = 587.863 \cdot lb$$

Total Surface of suspender rods

$$S := 4 \cdot \sum_{i=1}^{n_{max}} S_{n_i} - 2 S_{n_1} = 11.322\,m^2$$

$$S = 121.866 \cdot ft^2$$

Suspenders length for each member (i= 1 - 23)

$d_i =$ (ft)	$lsus_i =$ (ft)
3.445	1.667
3.492	1.714
3.634	1.856
3.87	2.092
4.202	2.423
4.628	2.849
5.148	3.37
5.764	3.986
6.475	4.697
7.282	5.504
8.184	6.406
9.182	7.404
10.277	8.498
11.468	9.689
12.755	10.977
14.141	12.362
15.623	13.845
17.204	15.426
18.884	17.106
20.663	18.884
22.541	20.763
24.519	22.741
26.598	24.82

Note:
di is the distance form main cable to the spanning cable.

lsusi is the suspender length for each i from 1 to 23.

NOTE: APPENDIX J & K WILL BE ATTACHED SEPARATE FROM MAIN REPORT

Chichica Foot Bridge

iDesign Final Report

Appendix J & K

Detailed Design Drawings & Selected Steelparts Lists

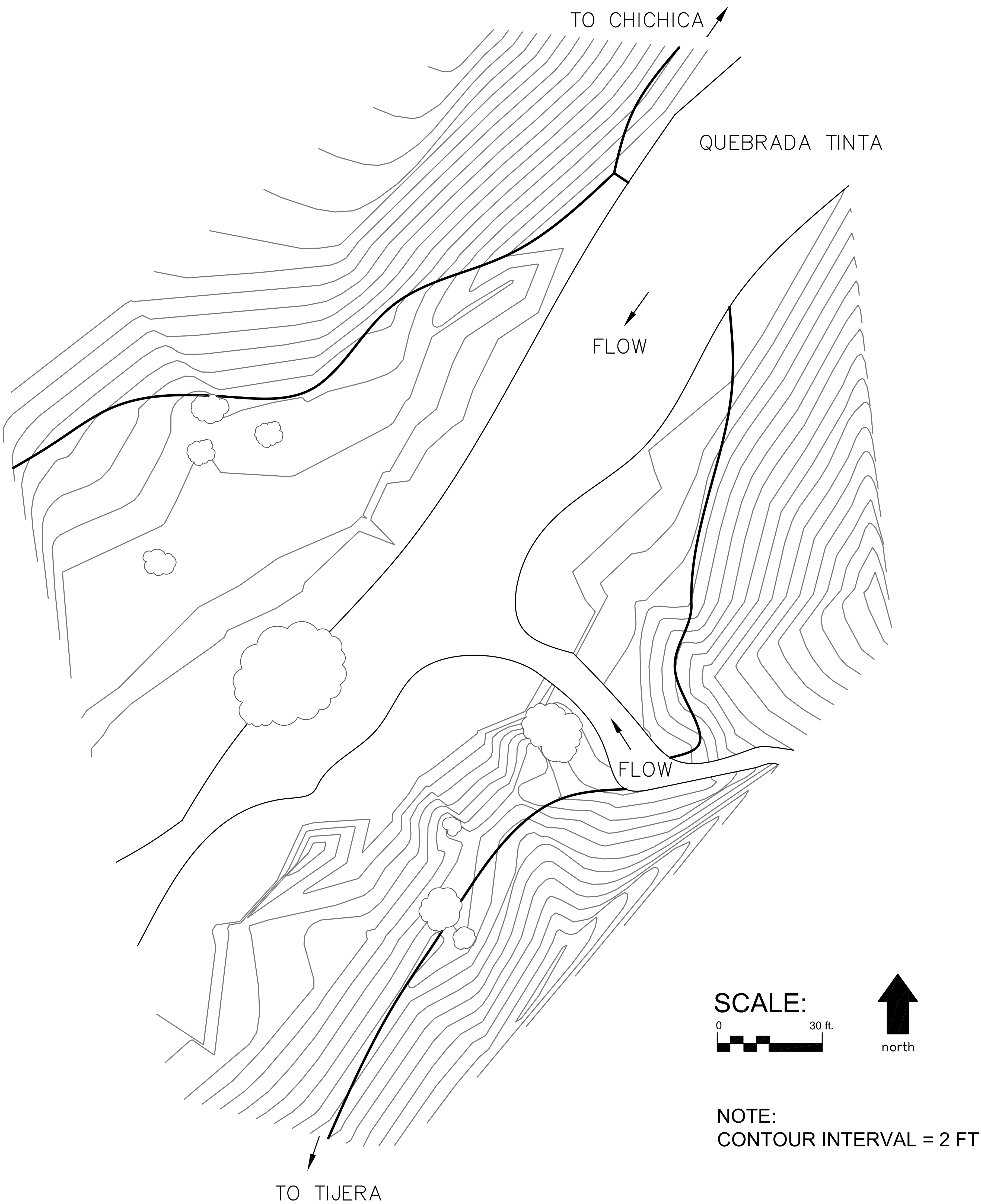
Michael Rood   Deanna Larson   Haobo Ma   Yingying Jin   Stephanie Watts-Garcia

Photo courtesy of Suspension Bridge at Clifton, courtesy of the Gutenberg Project *blogs.asee.org*

Michigan Technological University
Civil and Environmental Engineering Department
1400 Townsend Drive
Houghton, MI 49931

36 SB Consulting

Detailed Design Drawing Index

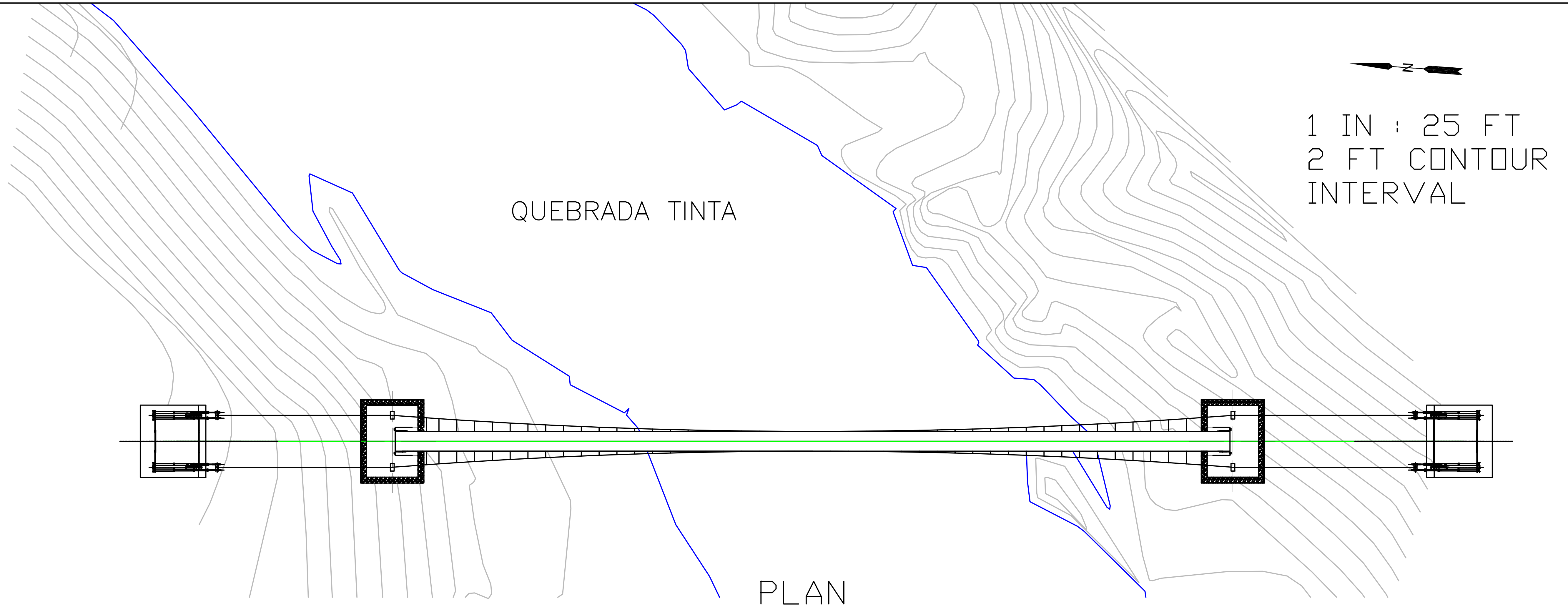


36 SB CONSULTING

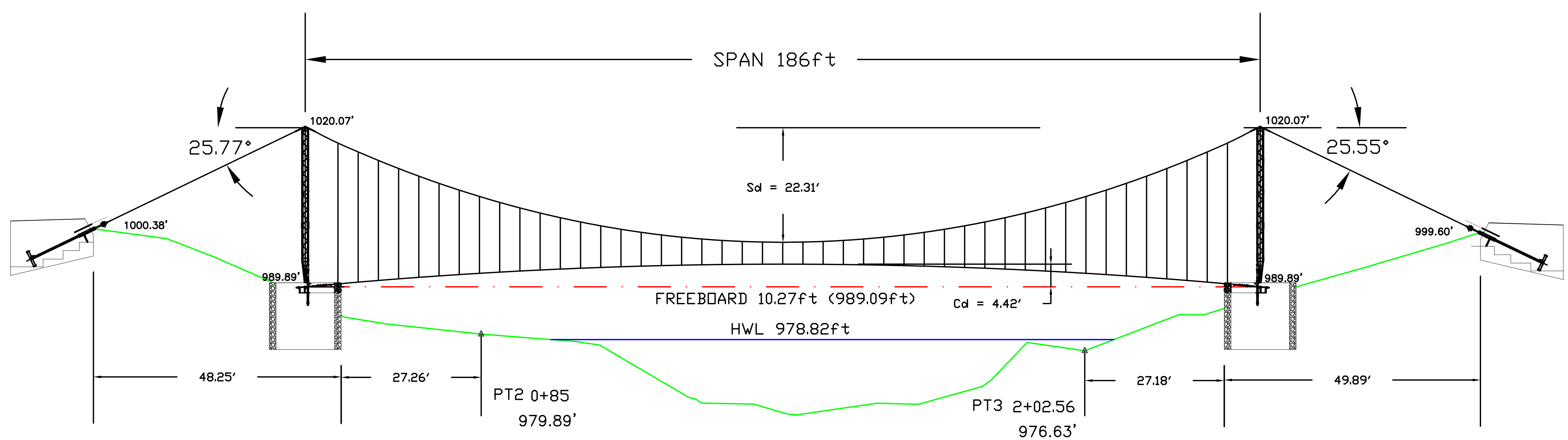
Site Topography

Drawn By: Michael Rood

Drawing # 1



PLAN



PROFILE

Footbridge Layout

Drawn By: Michael Rood

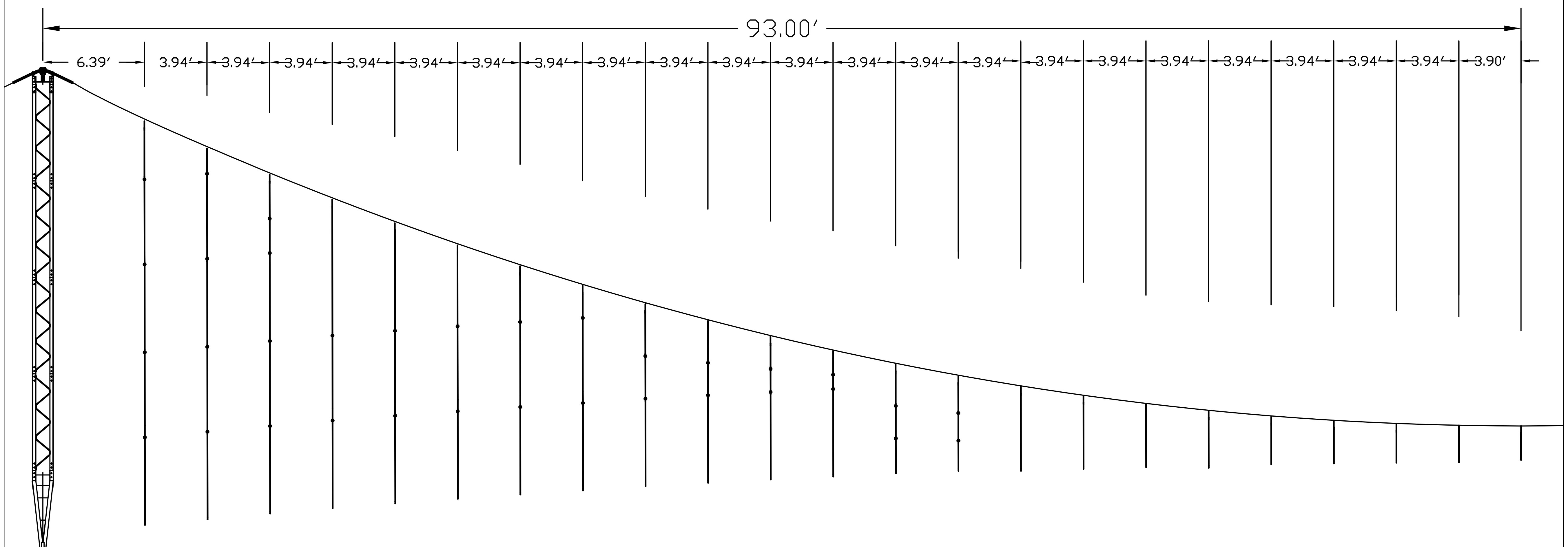
Drawing # 2

Notes:
Plan & Profile View

36 SB Consulting

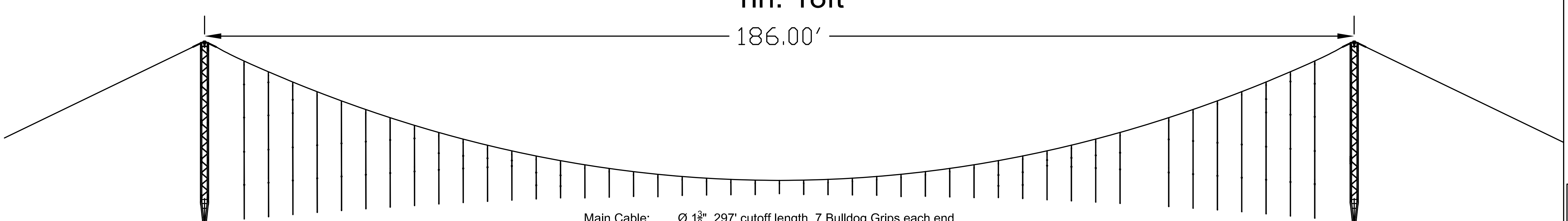
Halfway of the bridge with suspenders and tower

1in:7ft



Profile of the Bridge

1in: 18ft



Main Cable: Ø $1\frac{3}{8}$", 297' cutoff length, 7 Bulldog Grips each end.
Spanning Cable: Ø 1", 193' cutoff length, 5 Bulldog Grips each end.
Suspenders: Ø $\frac{1}{2}$", 90 total for bridge.

Suspenders Design

Drawn By: Yingying Jin

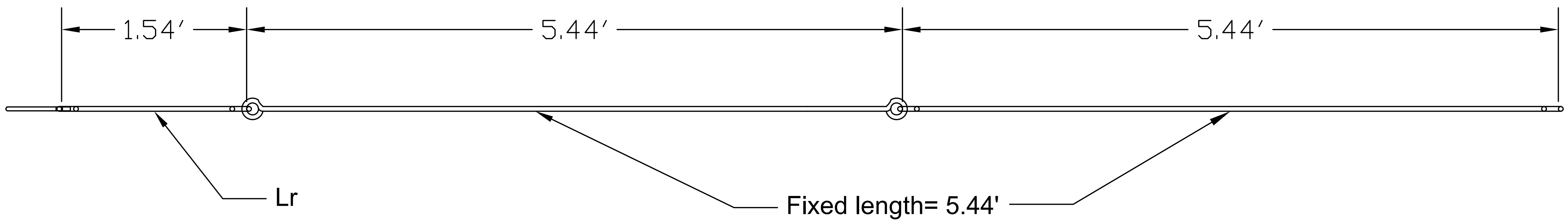
Drawing # 3-1

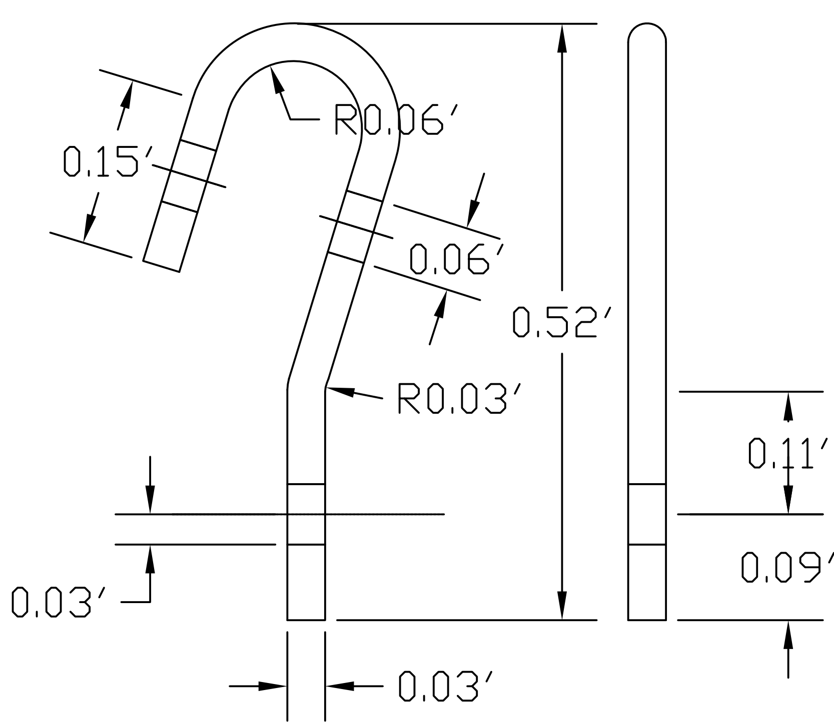
Notes: See Appendix K for part details

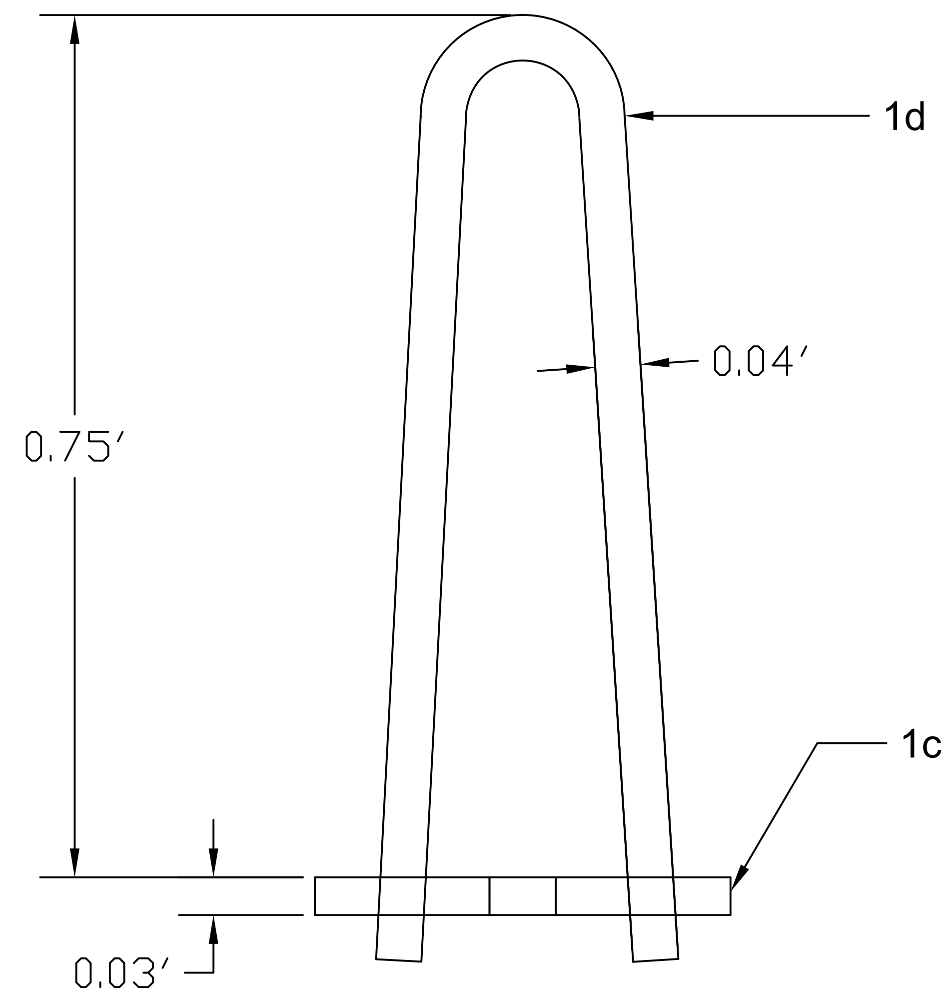
36 SB Consulting

Suspender Design Details

1IN : 1FT







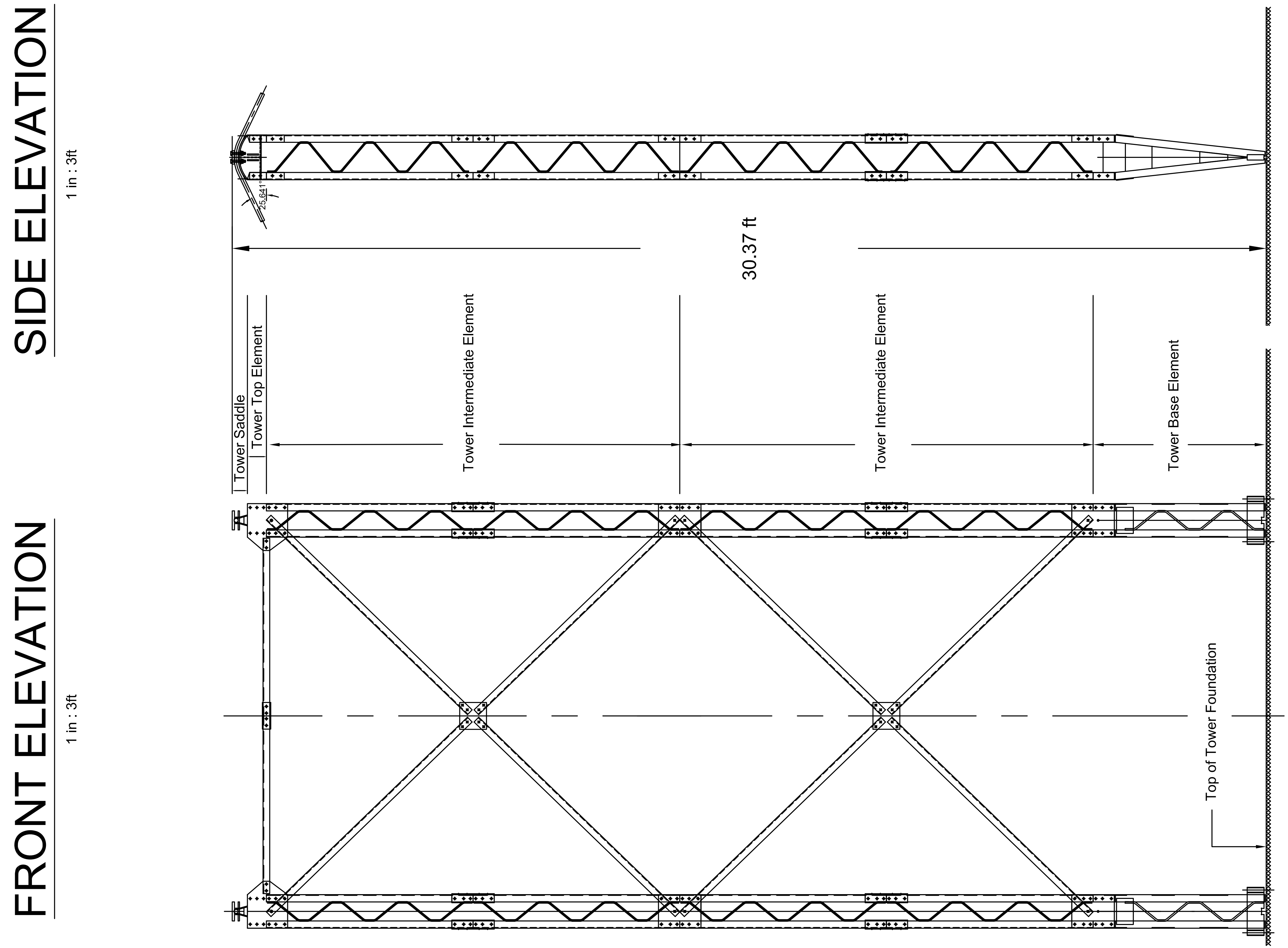
Suspenders Design

Drawn By: Yingying Jin

Drawing # 3-2

Notes: See Appendix K for part details

36 SB Consulting



Tower Assembly

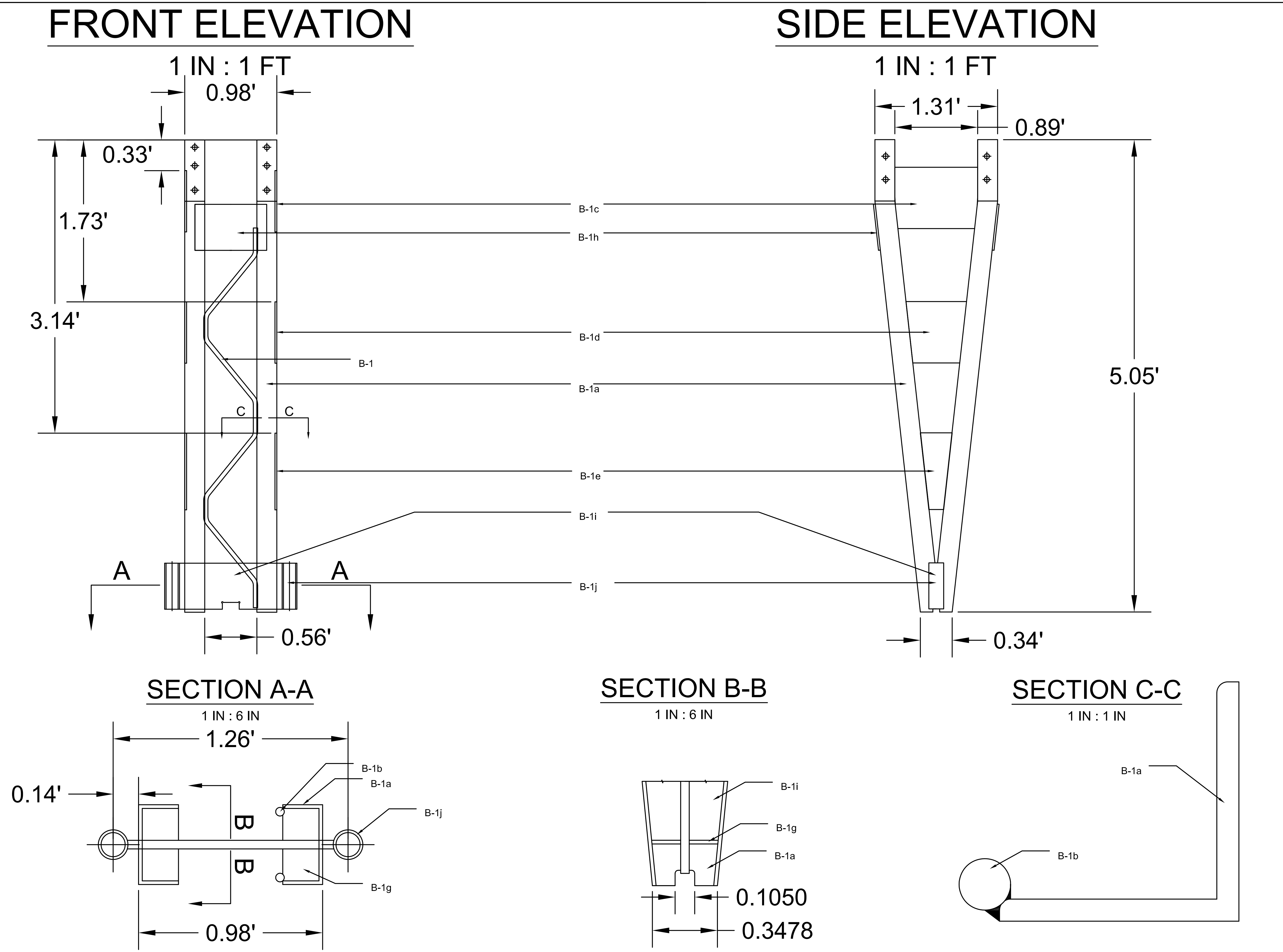
Drawn By: Deanna Larson

Drawing # 4-1

Notes:

See following drawings for element details

36 SB Consulting



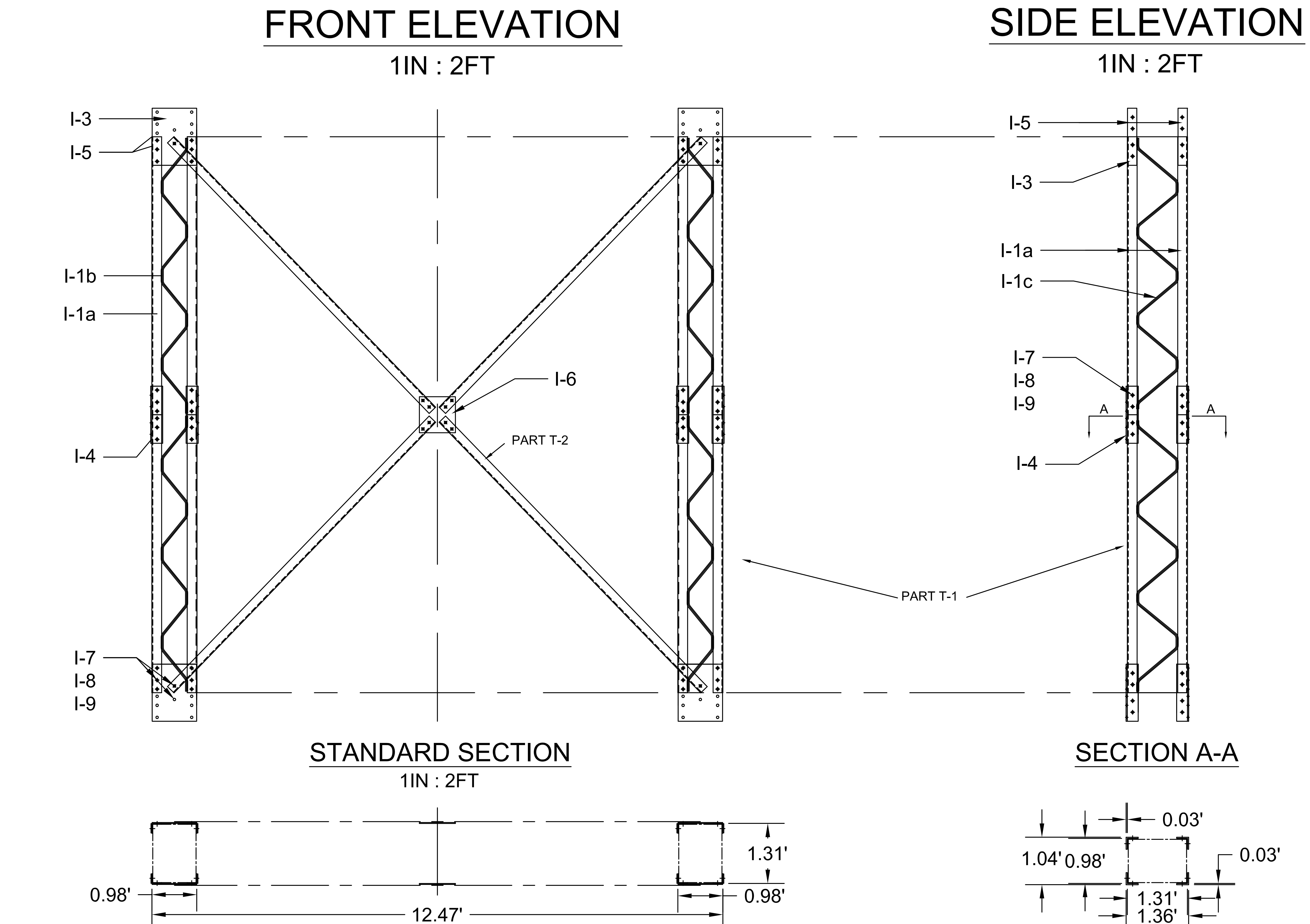
Tower Base Element

Drawn By: Deanna Larson

Drawing # 4-2

Notes:
See Appendix K for part details

36 SB CONSULTING



Tower Intermediate Element

Drawn By: Deanna Larson

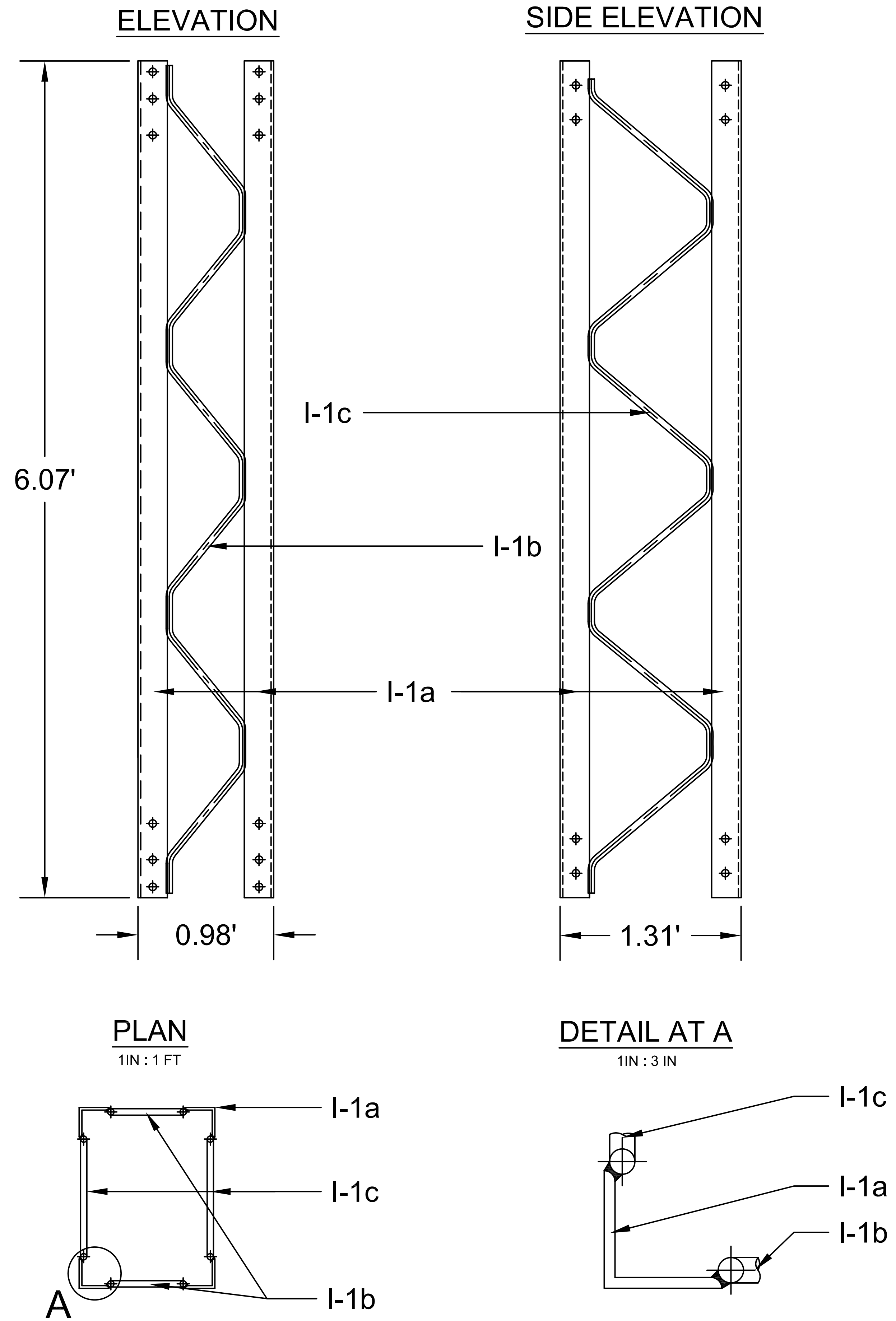
Drawing # 4-3

Notes: See Appendix K for part details

36 SB Consulting

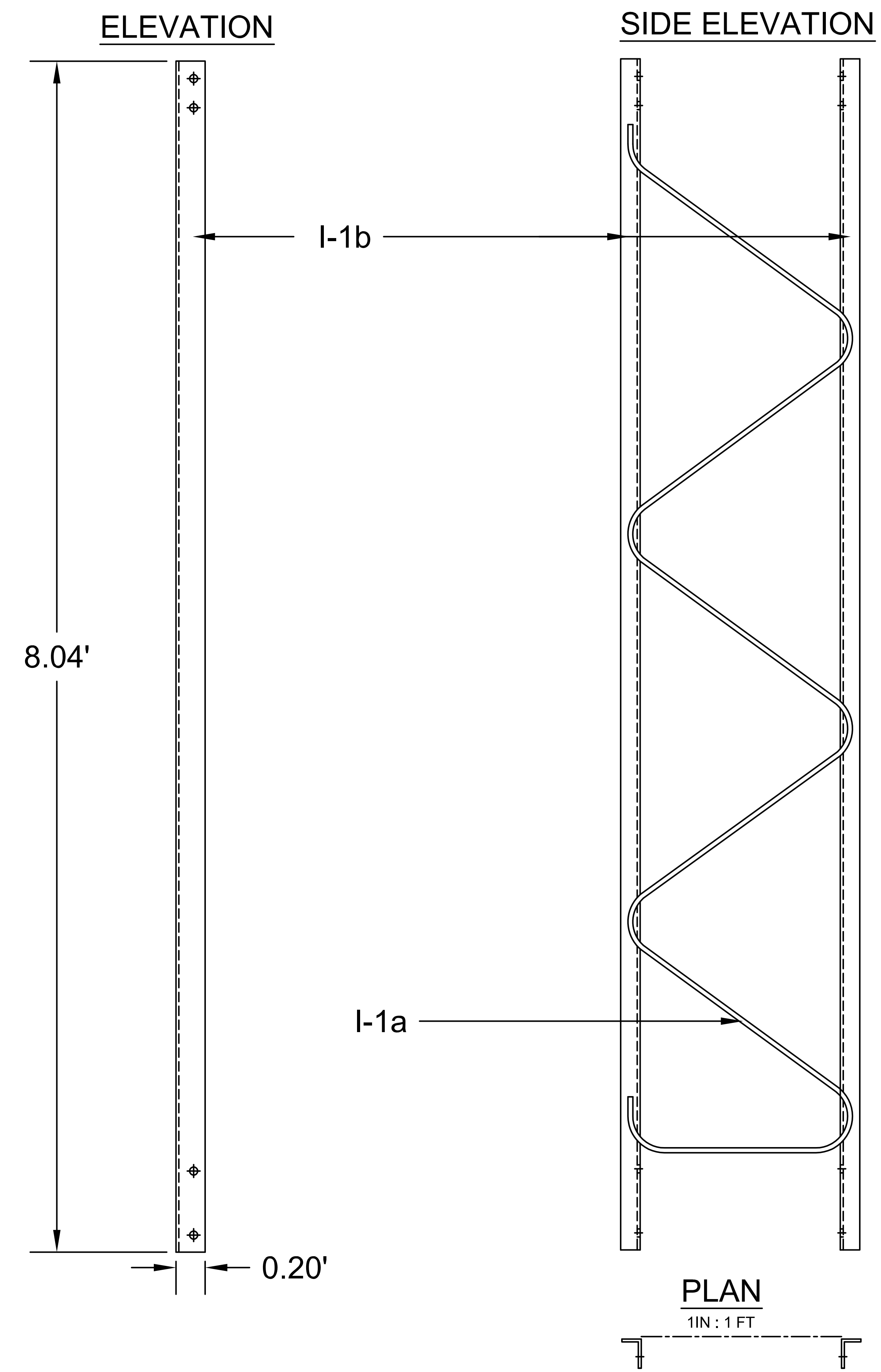
WELDING DETAIL OF PART I-1

1IN : 1 FT



WELDING DETAIL OF PART I-2

1IN : 1 FT



Tower Intermediate Element

Drawn By: Deanna Larson

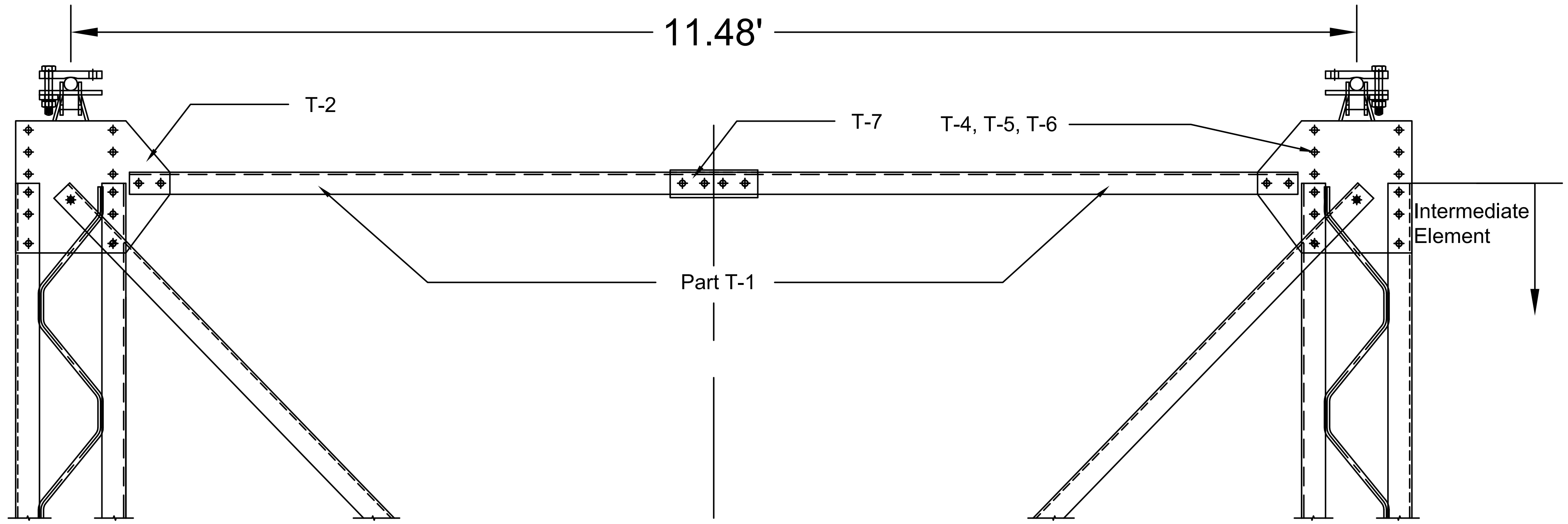
Drawing # 4-4

Notes: See Appendix K for part details

36 SB Consulting

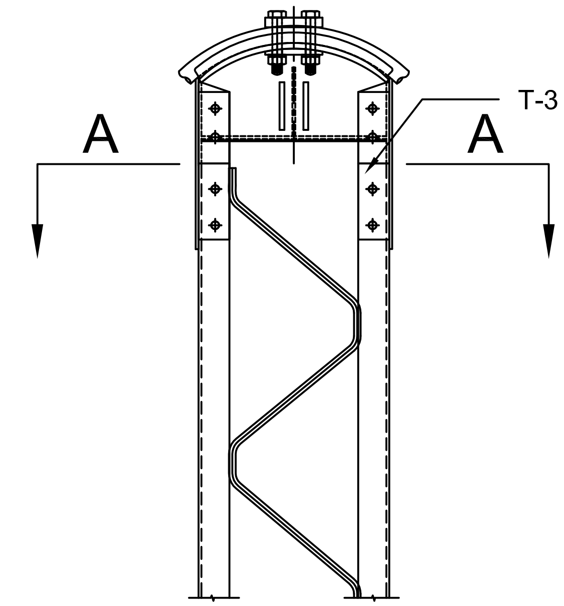
FRONT ELEVATION

1 IN : 1.5 FT



SIDE ELEVATION

1 IN : 1.5 FT

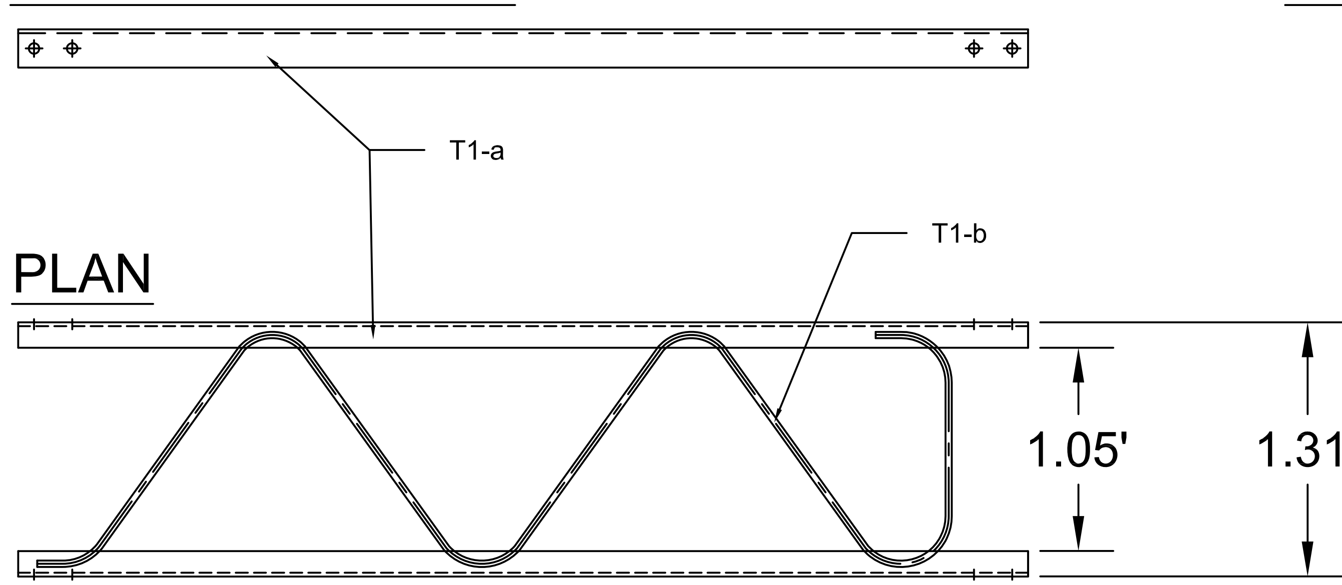


WELDING DETAIL OF PART T-1

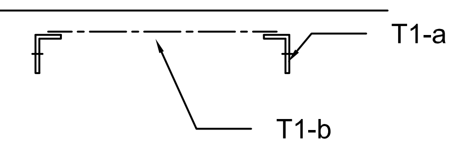
1 IN : 1 FT

FRONT ELEVATION

PLAN

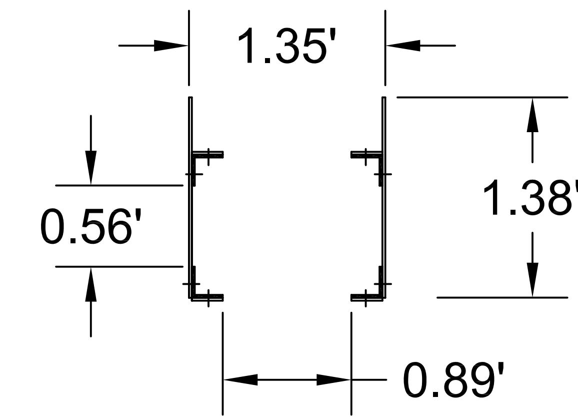


SIDE ELEVATION



PLAN VIEW A-A

1 IN : 1.5 FT



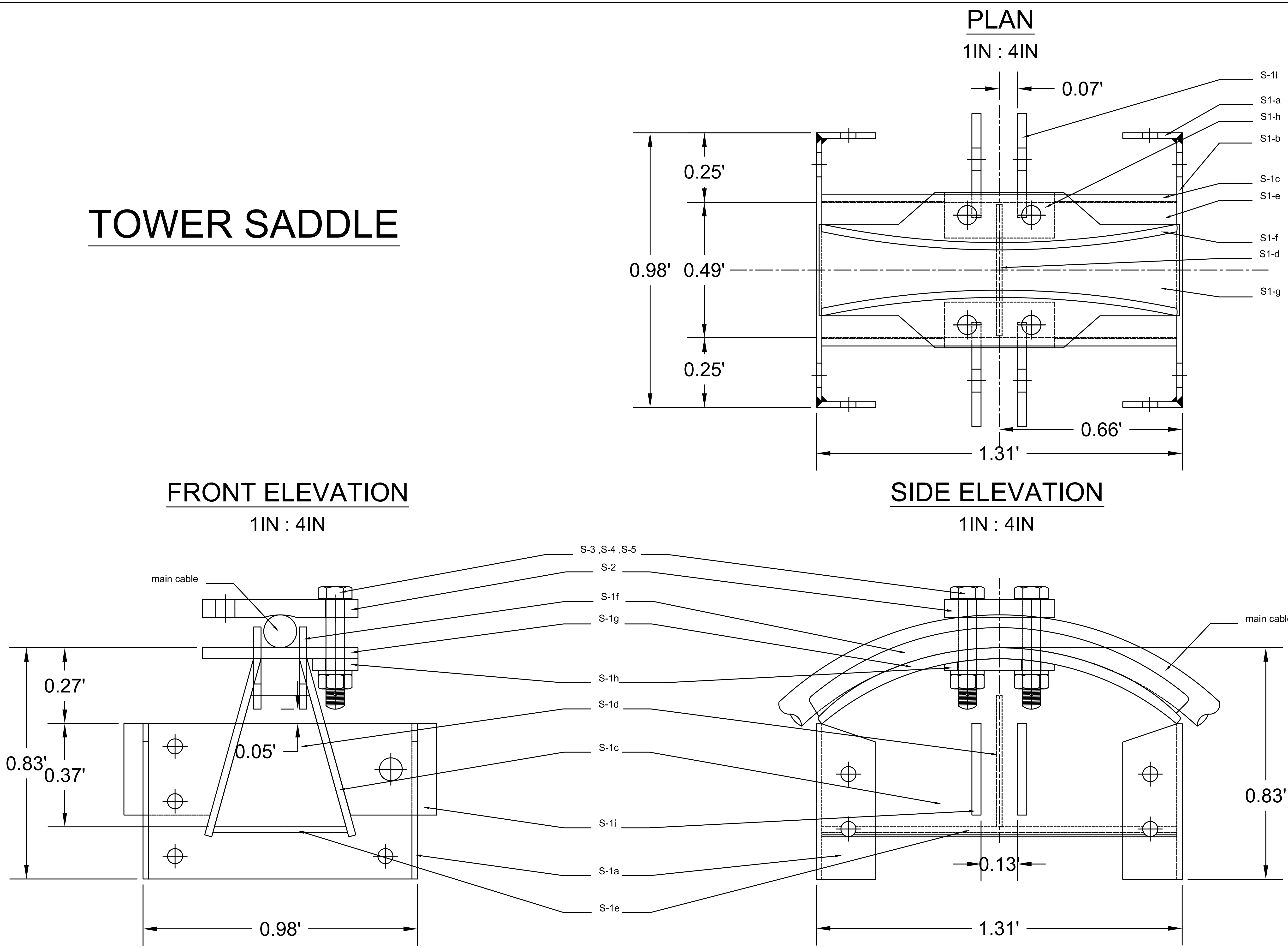
Tower Top Element

Drawn By: Deanna Larson

Drawing # 4-5

Note: See Appendix K for part details

36 SB Consulting



Tower Saddle

Drawn By: Deanna Larson

Drawing # 4-6

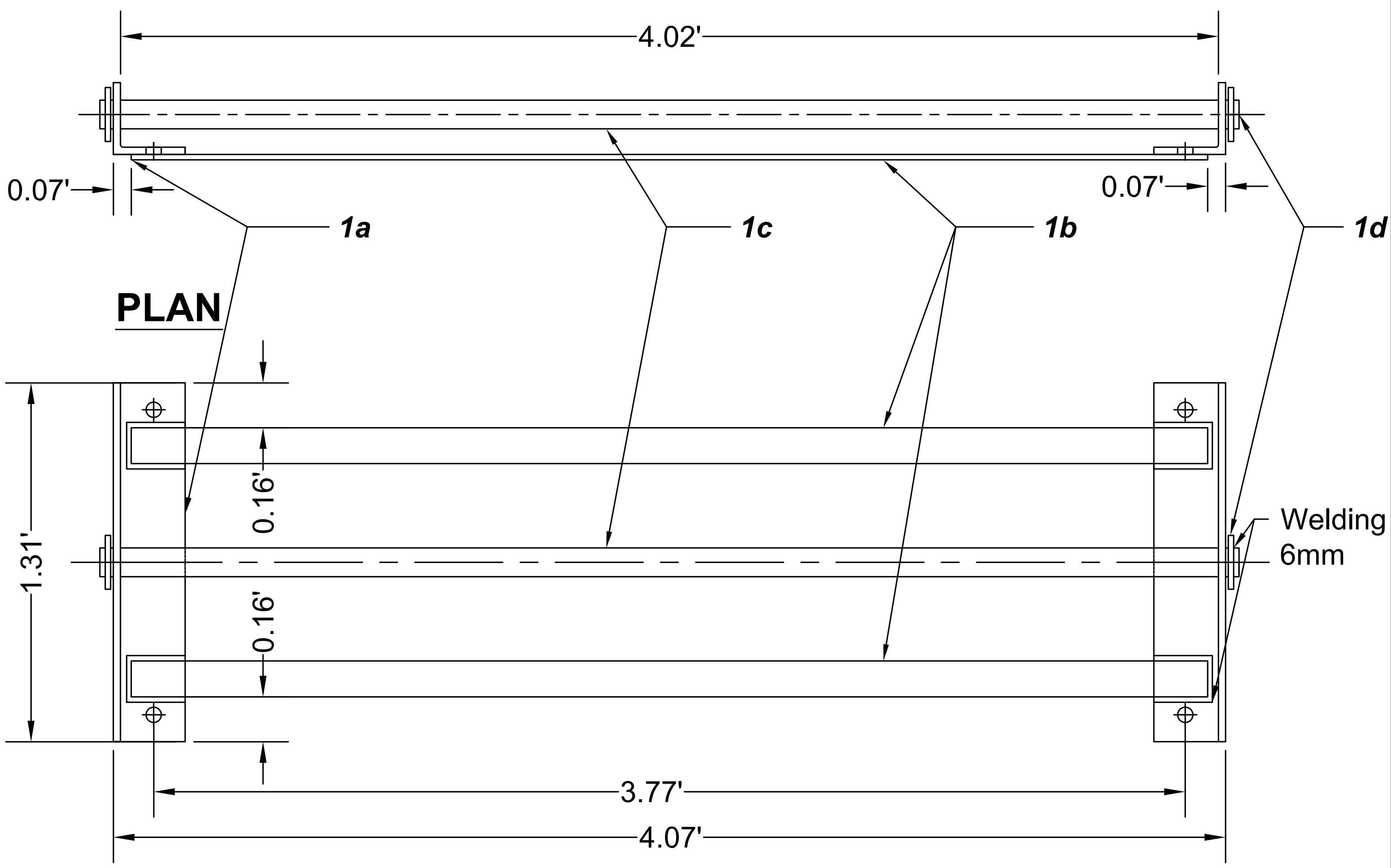
Notes:
See Appendix K for part details

36 SB Consulting

WELDING DETAIL OF PART 1

1 IN : 6 IN

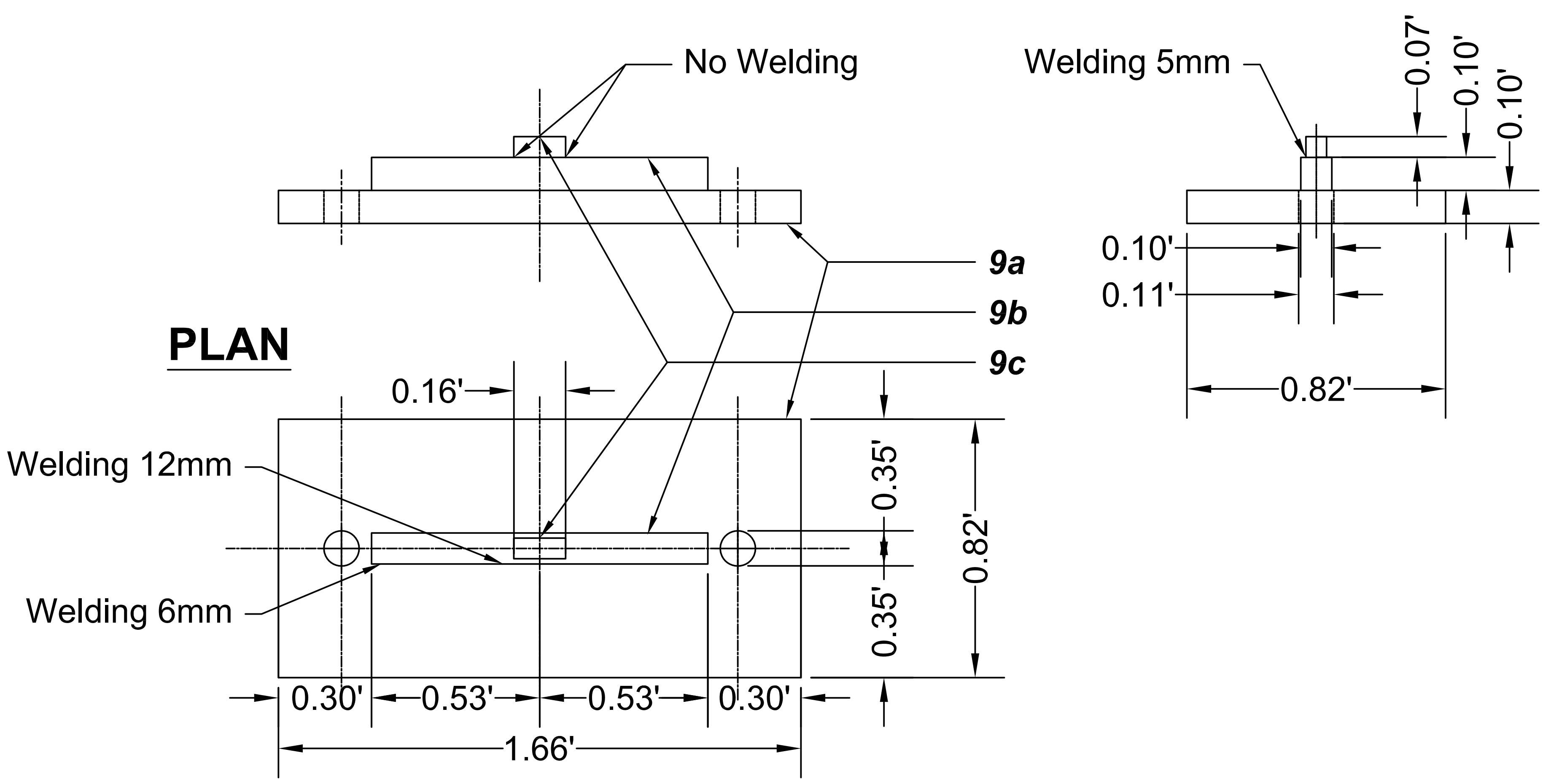
FRONT ELEVATION



WELDING DETAIL OF PART 9

1 IN : 6 IN

FRONT ELEVATION



Walkway and Tower Foundation

Drawn By: Michael Rood
Haobo Ma

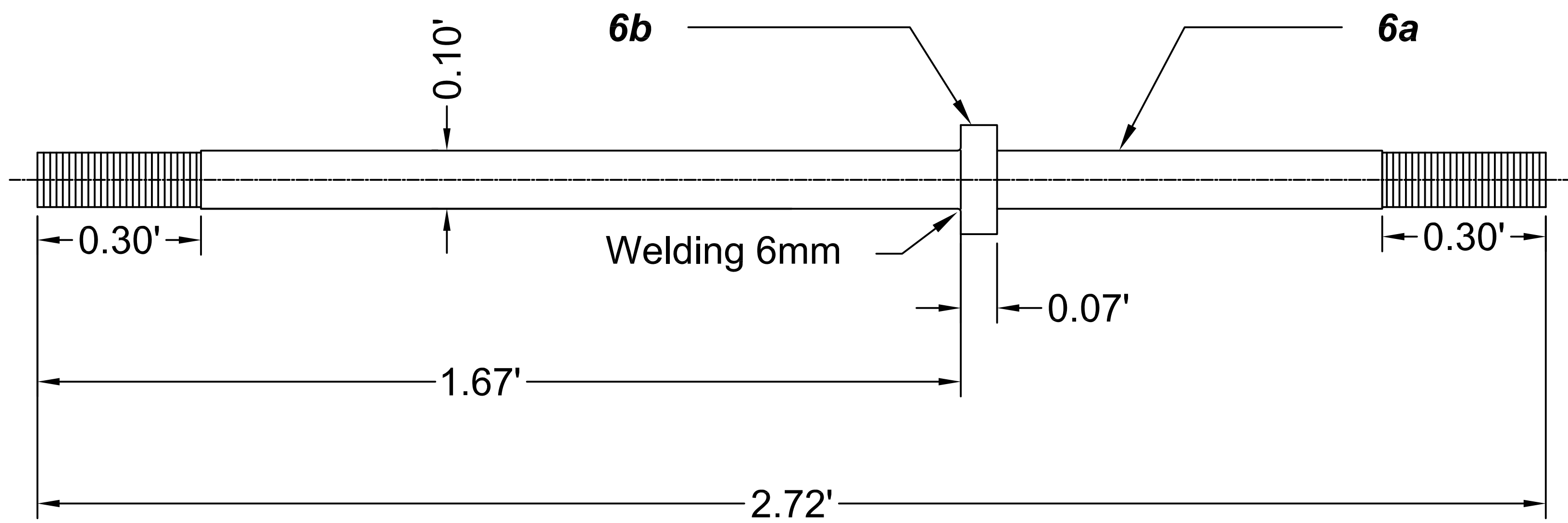
Drawing #
5 - 1

Notes:
Welding details

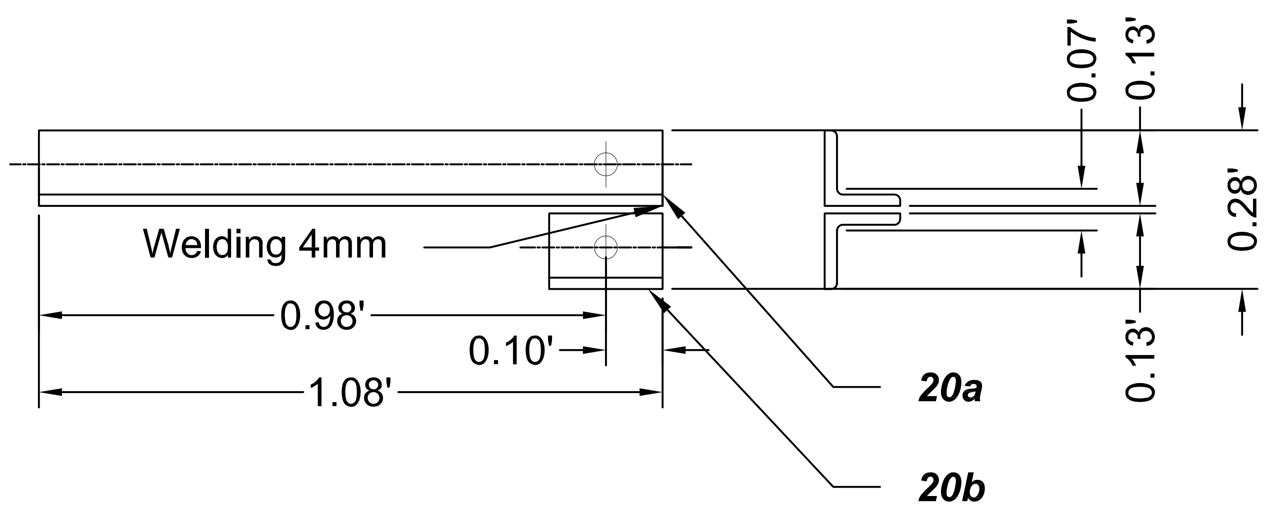
WELDING DETAILS OF PARTS 6 & 20

1IN : 4IN

WELDING DETAIL OF PART 6



WELDING DETAIL OF PART 20



Walkway and Tower Foundation

Drawn By: Haobo Ma

Drawing #
5 - 2

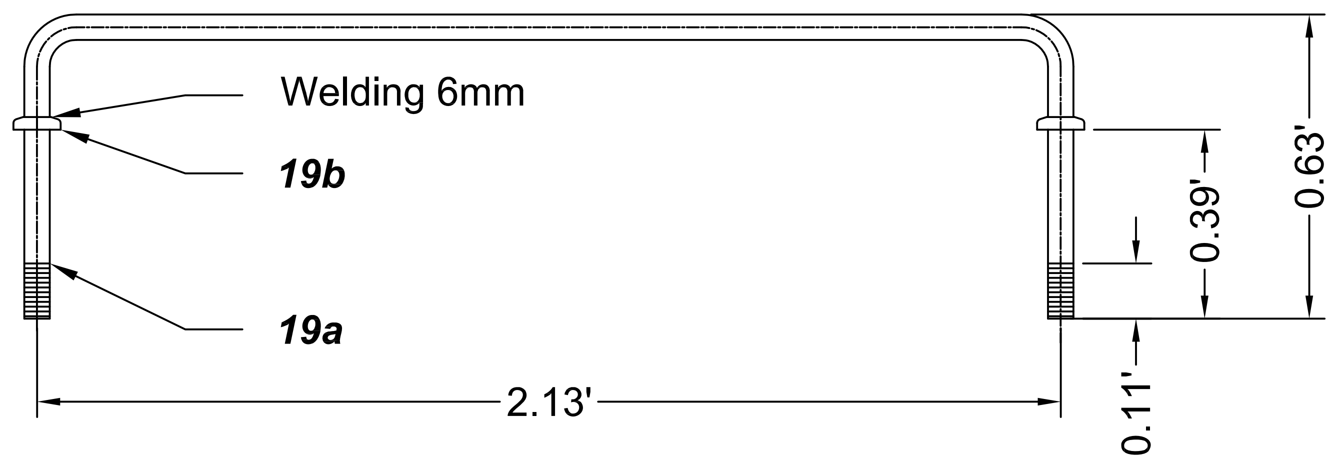
Notes:
Welding details

36 SB Consulting

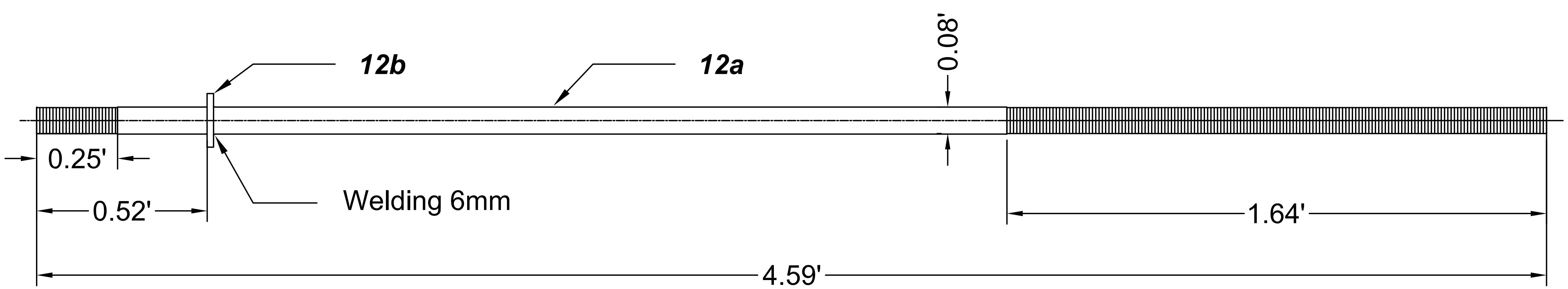
WELDING DETAILS OF PARTS 19 & 12

1IN : 5 IN

WELDING DETAIL OF PART 19



WELDING DETAIL OF PART 12



Walkway and Tower Foundation

Drawn By: Haobo Ma

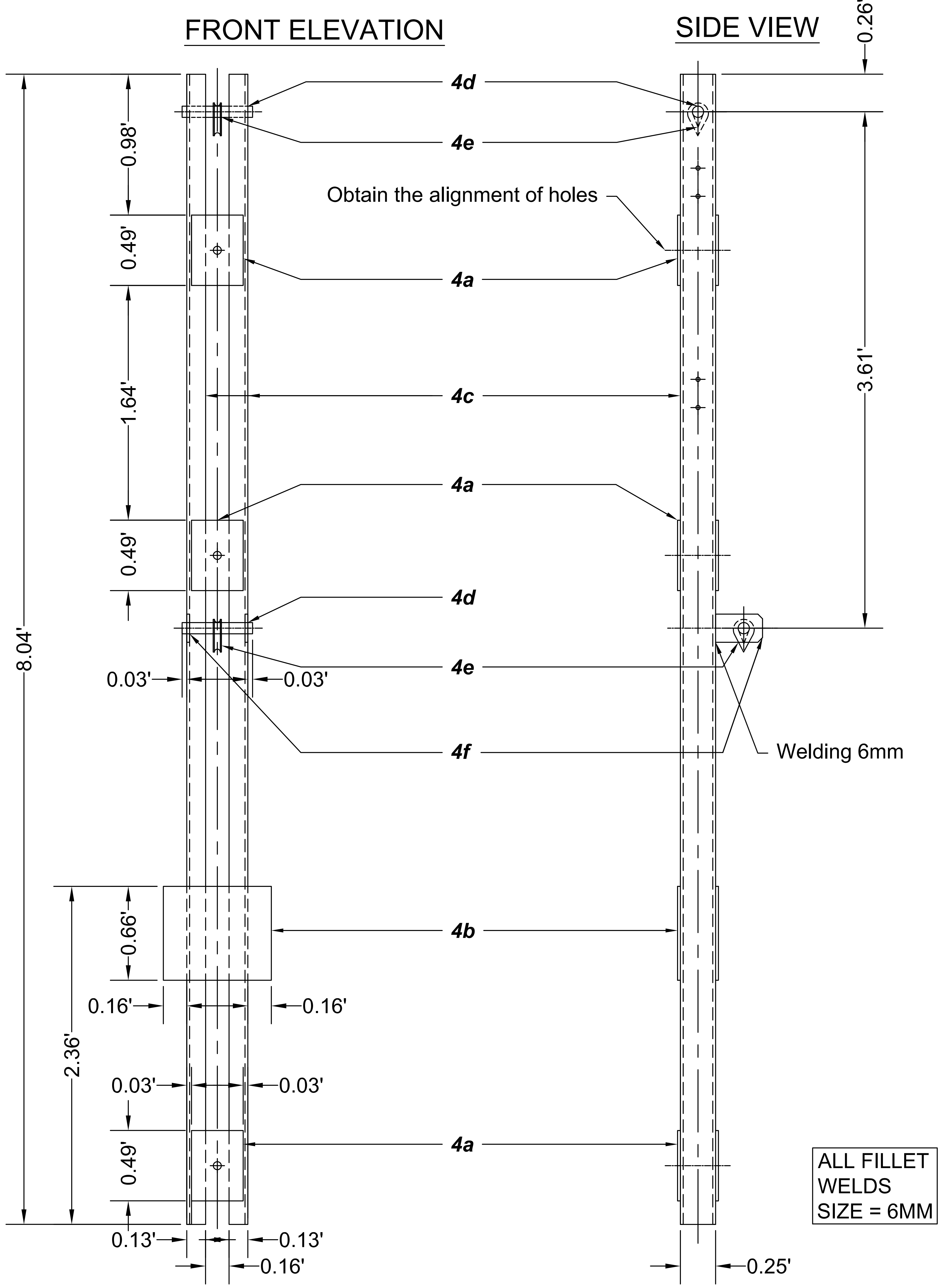
Drawing # 5 - 3

Notes: Welding details

36 SB Consulting

WELDING DETAIL OF PART 4

1 IN : 6 IN



36 SB CONSULTING

Walkway and Tower Foundation

Drawn By: Michael Rood
Haobo Ma

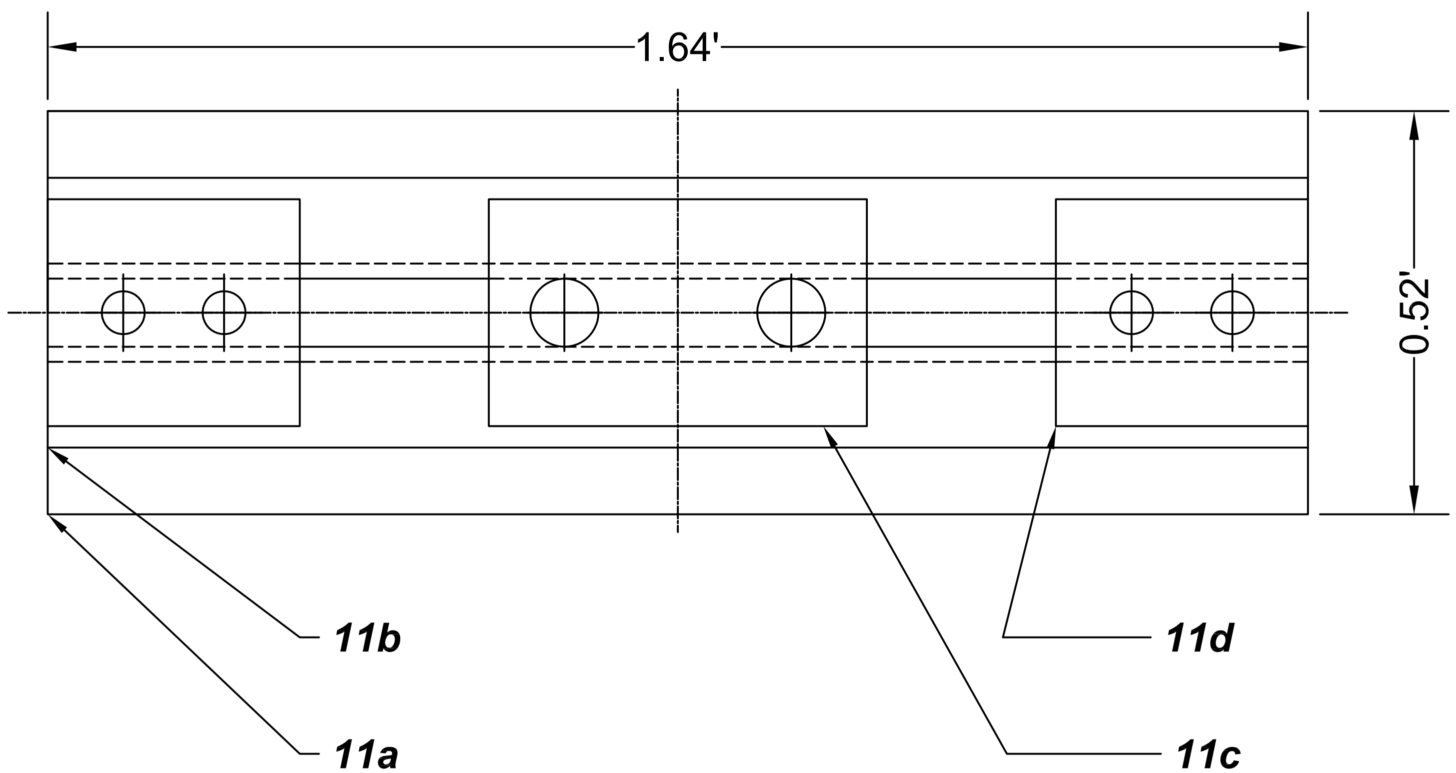
Drawing #
5 - 4

Notes:
Welding details

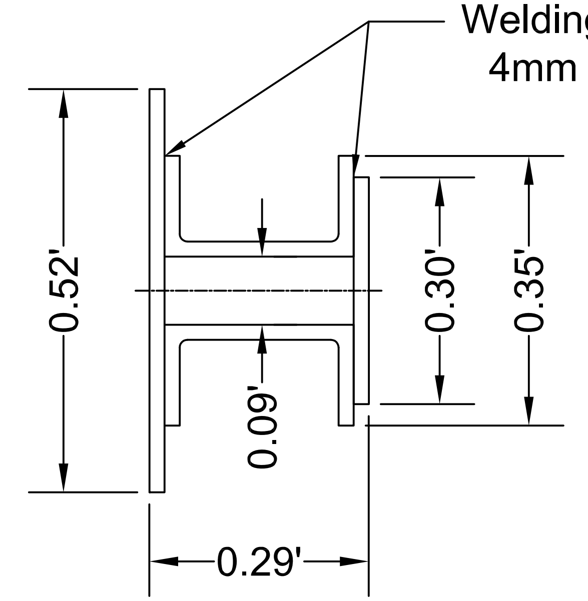
WELDING DETAIL OF PART 11

1 IN : 3 IN

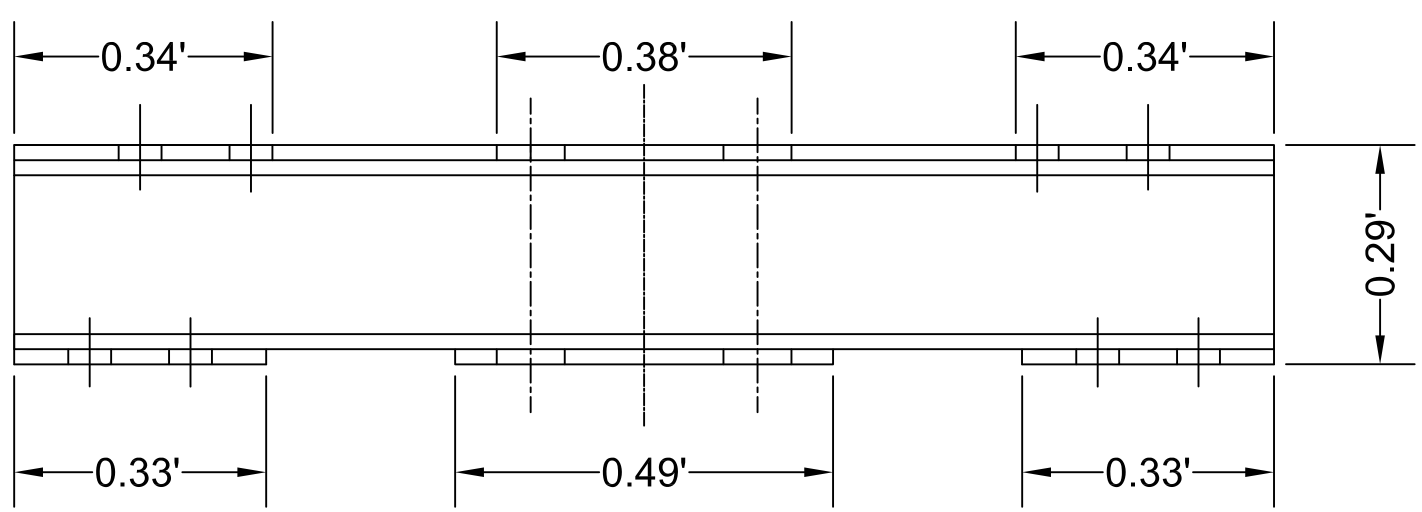
ELEVATION



END VIEW



PLAN



Walkway and Tower Foundation

Drawn By: Michael Rood
Haobo Ma

Drawing #
5 - *5*

Notes:
Welding details

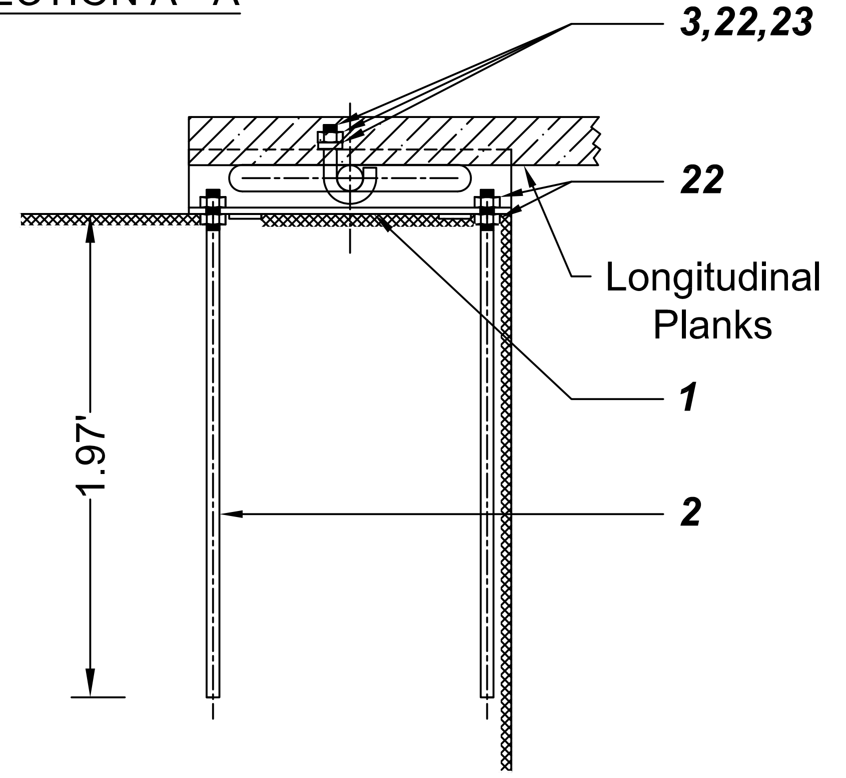
36 SB Consulting

ASSEMBLY DETAILS - 1

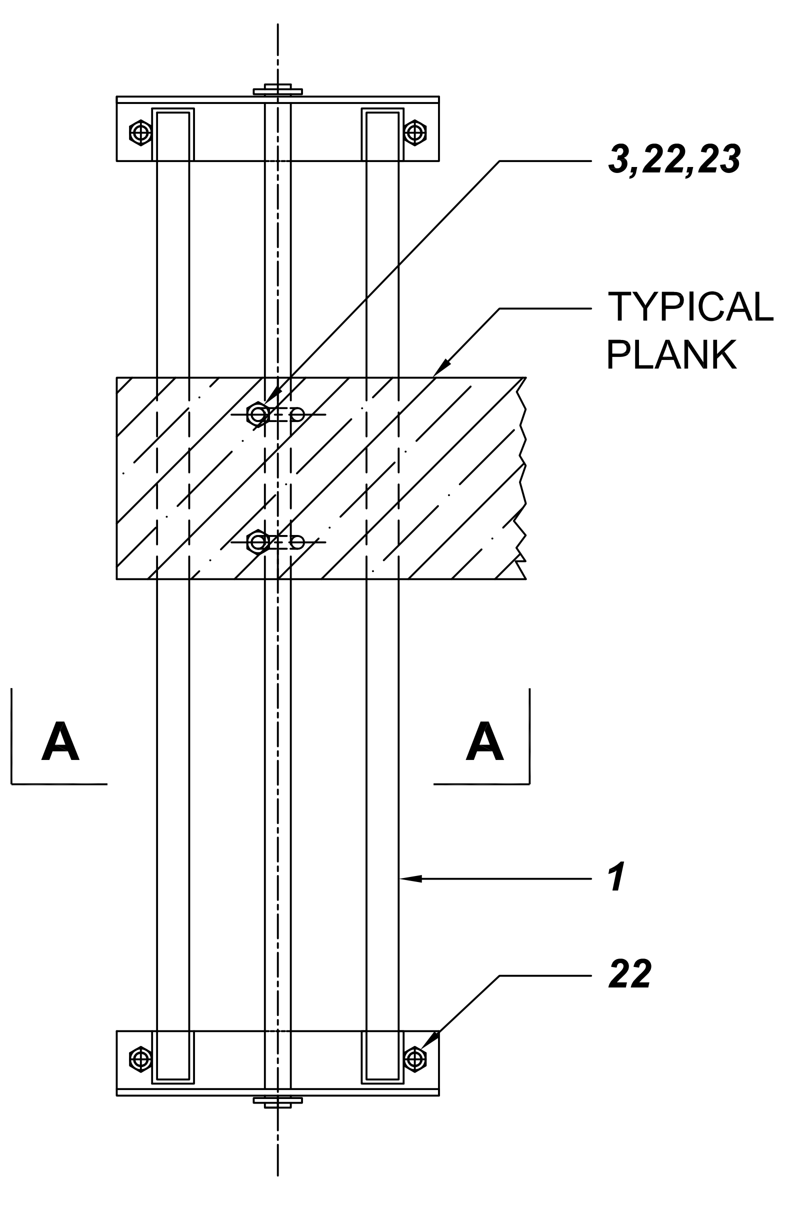
FIXING OF WALKWAY PLANKS

1 IN : 1 FT

SECTION A - A

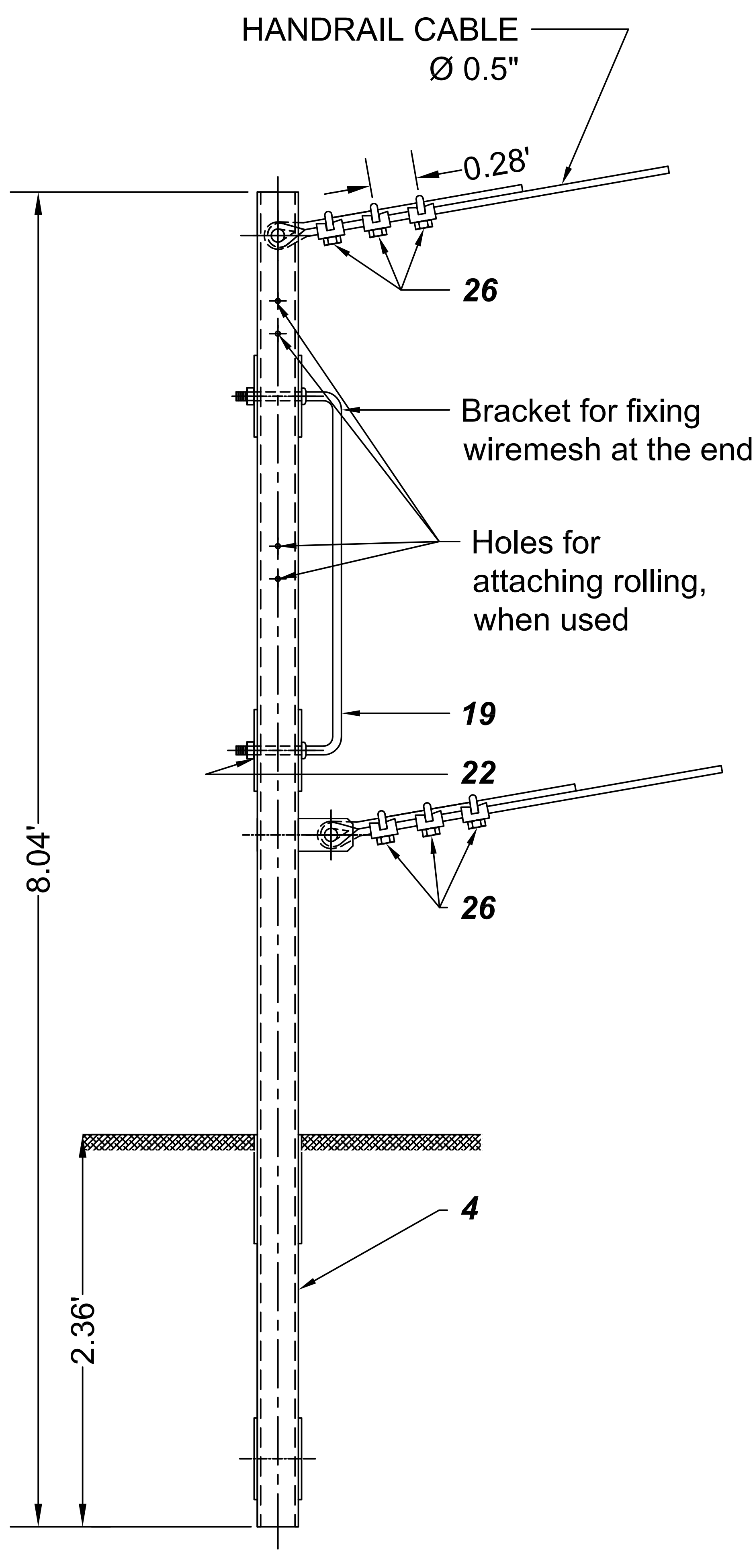


PLAN



HANDRAIL AND FIXATION CABLE ANCHORAGE

1 IN : 1 FT



Walkway and Tower Foundation

Drawn By: Michael Rood Haobo Ma

Drawing # 5 - 6

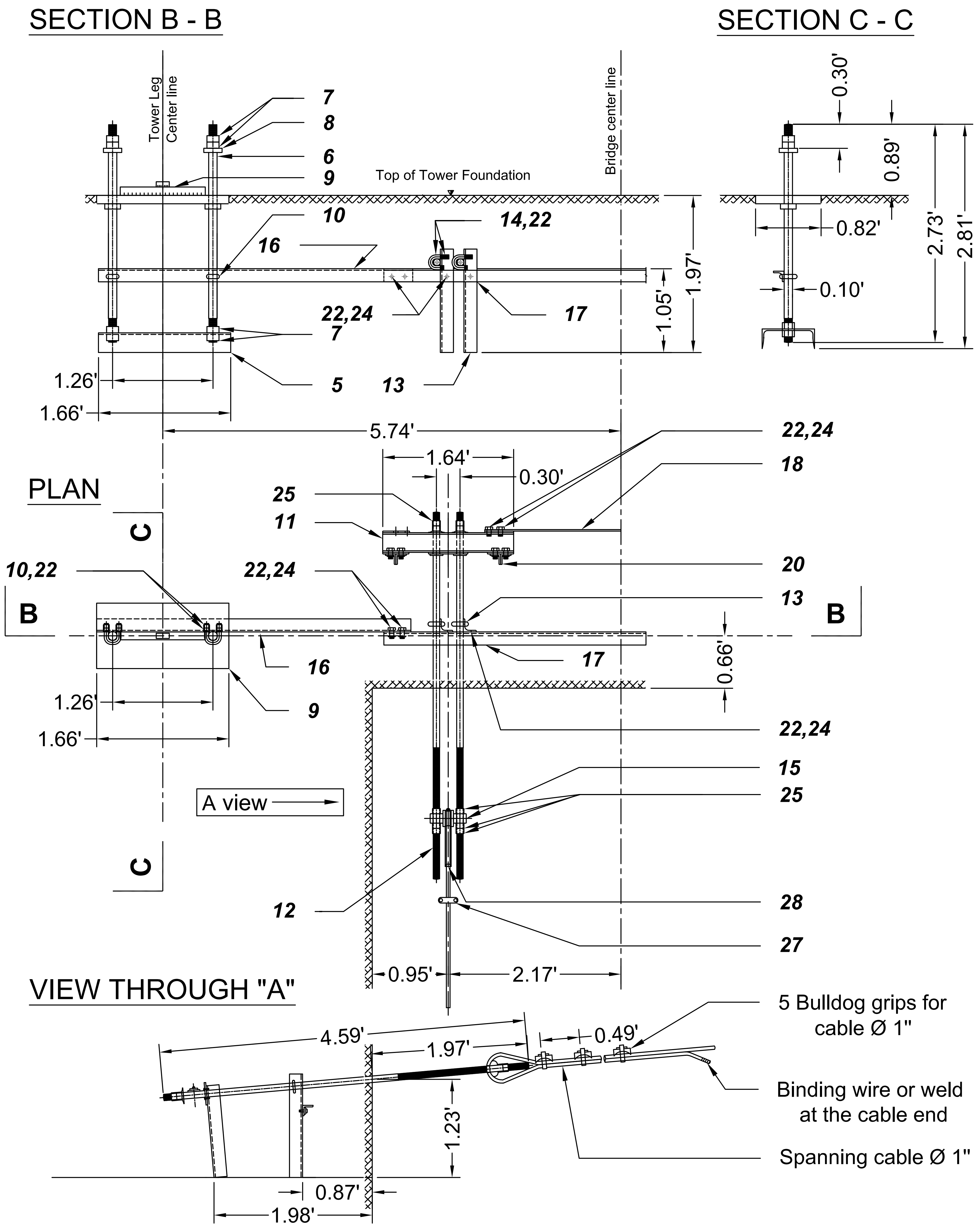
Notes: Assembly Details

36 SB Consulting

ASSEMBLY DETAILS - 2

1IN : 1FT

WALKWAY AND TOWER FOUNDATION



36 SB CONSULTING

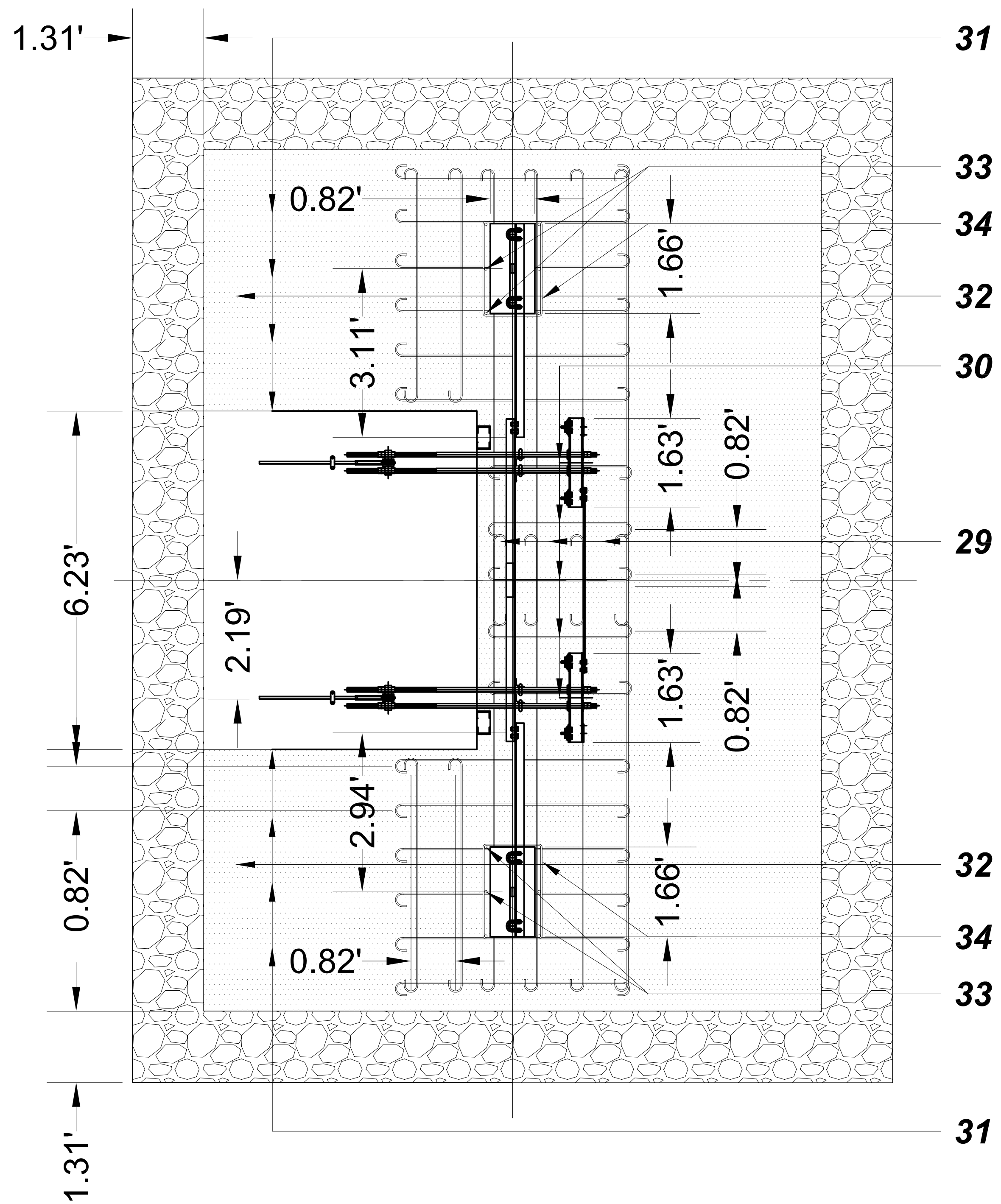
Notes: Assembly Details

Drawing # 5 - 7

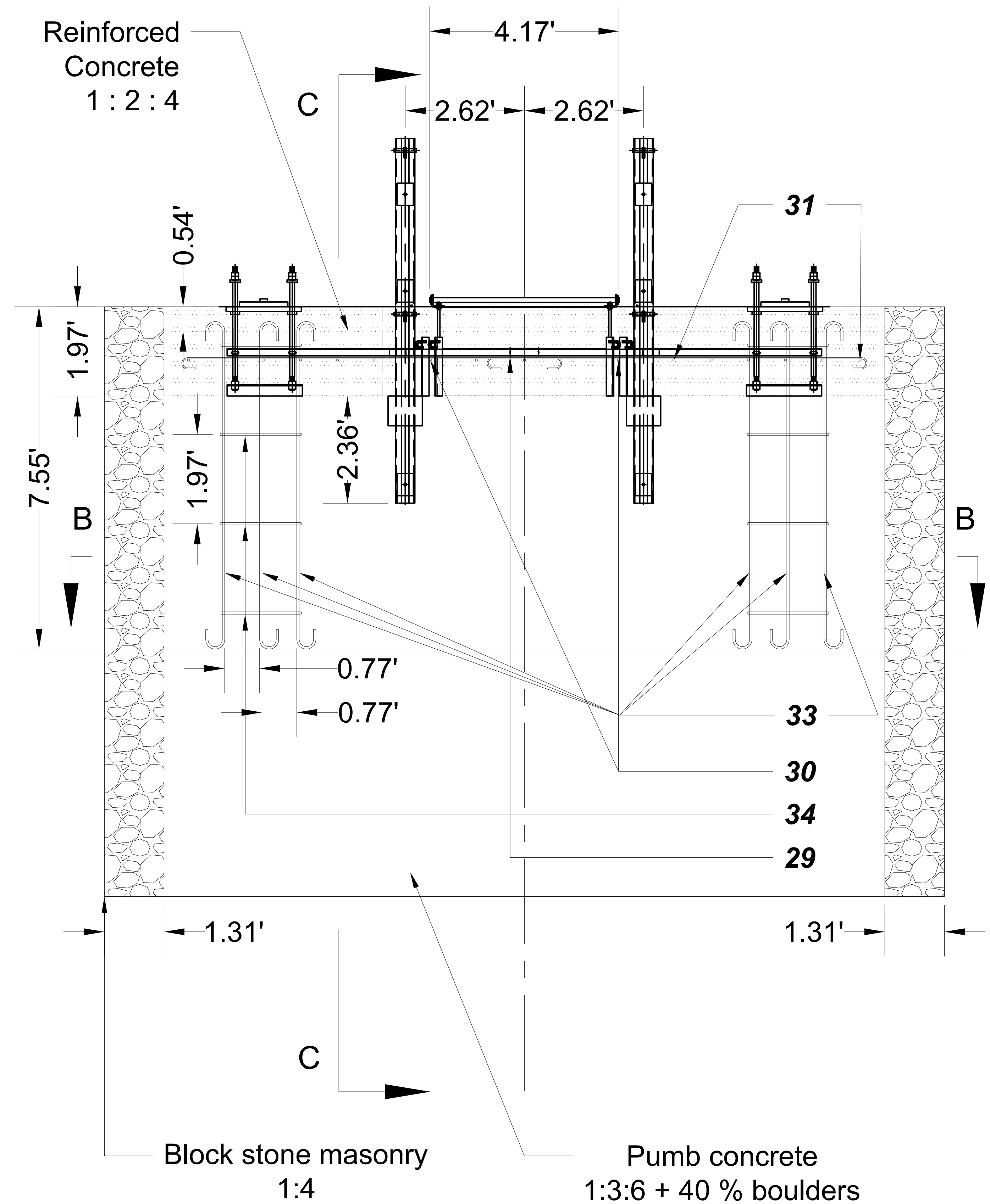
Drawn By: Haobo Ma

Walkway and Tower Foundation

SECTION B-B
1 IN : 3 FT



SECTION A-A
1 IN : 3 FT



Walkway and Tower Foundation

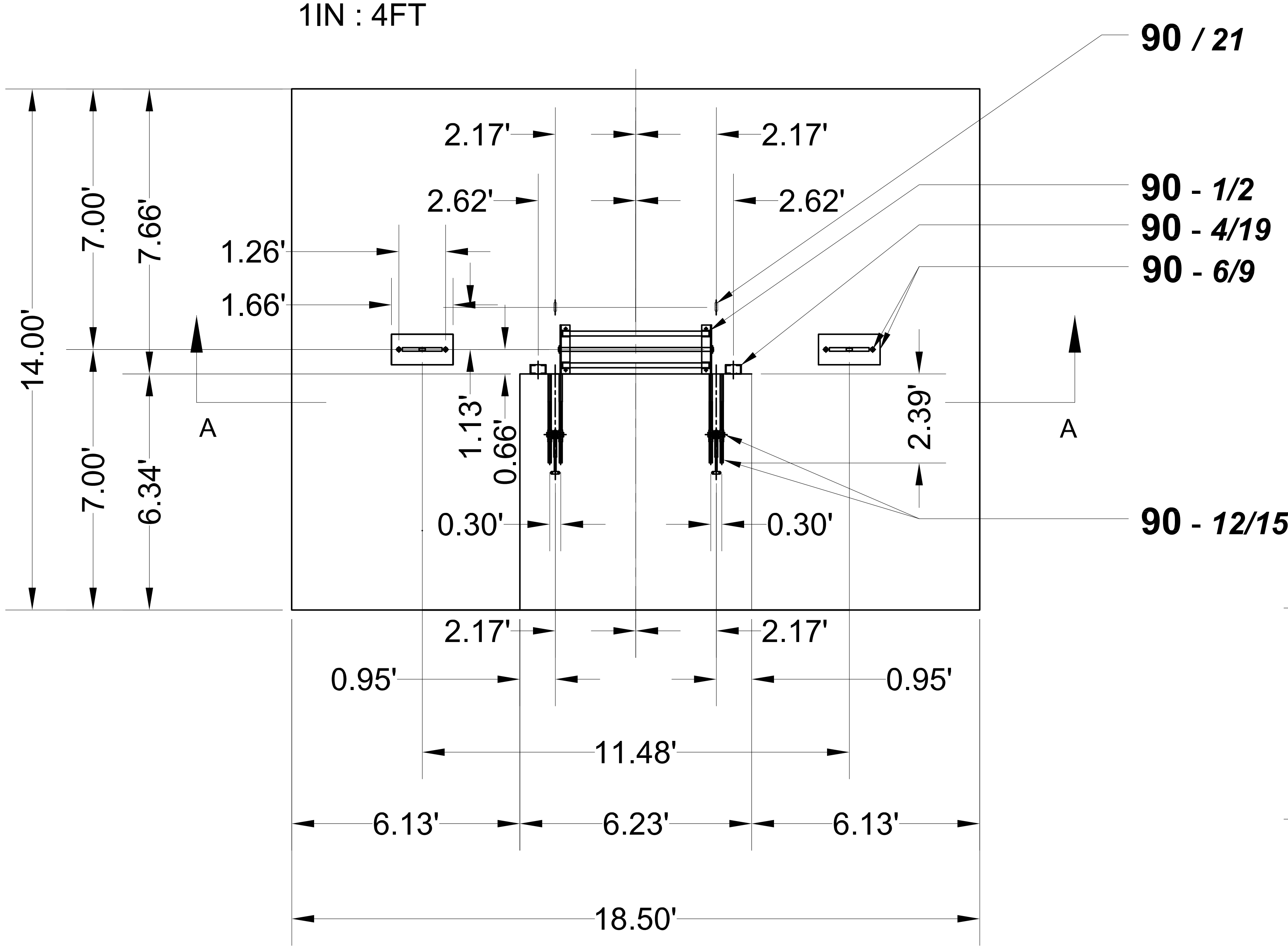
Drawn By: Michael Rood
Haobo Ma

Drawing #
5 - *8*

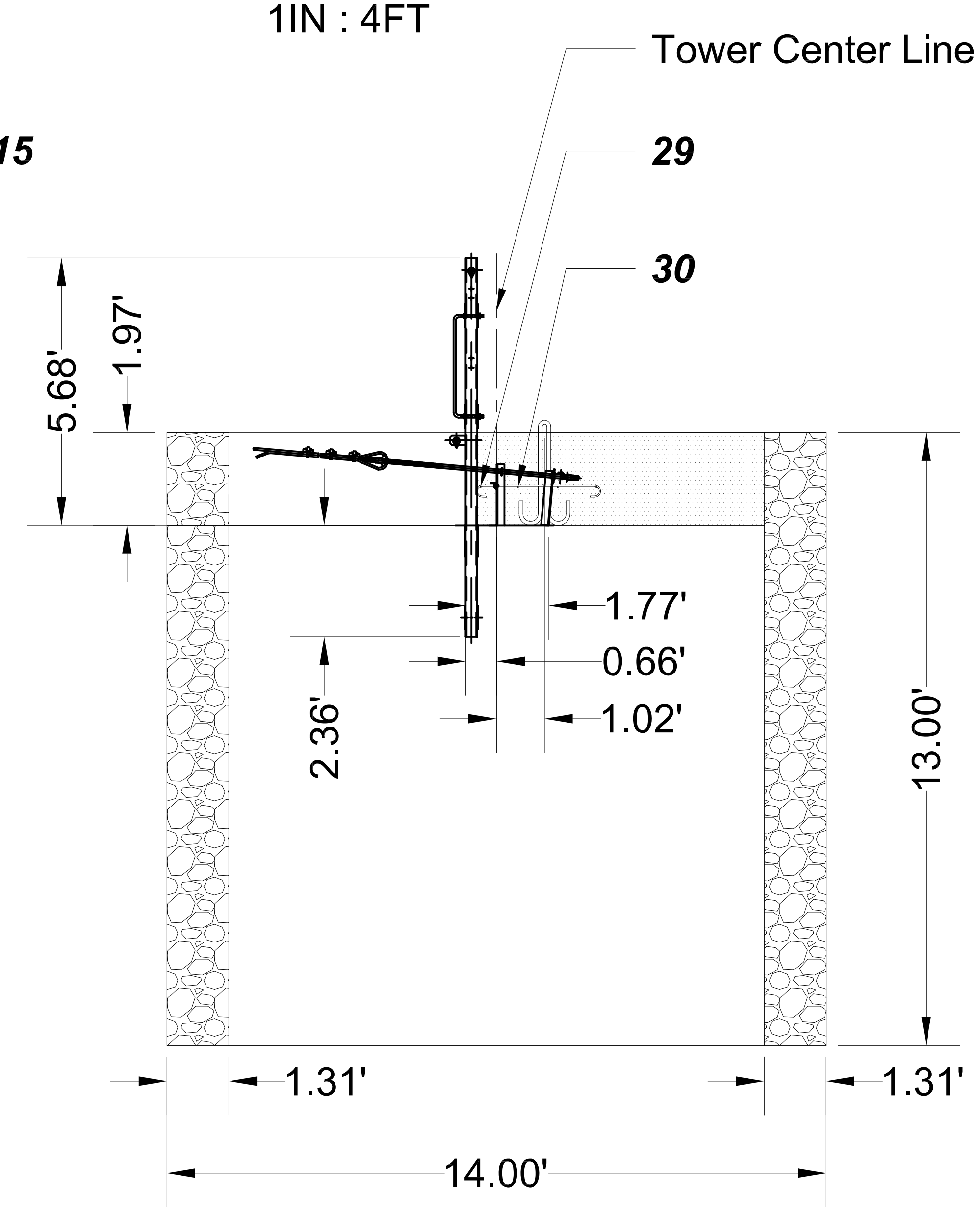
Notes:
Sections & Plan View

36 SB CONSULTING

PLAN
1IN : 4FT



SECTION C-C
1IN : 4FT



Walkway and Tower Foundation

Drawn By: Michael Rood
Haobo Ma

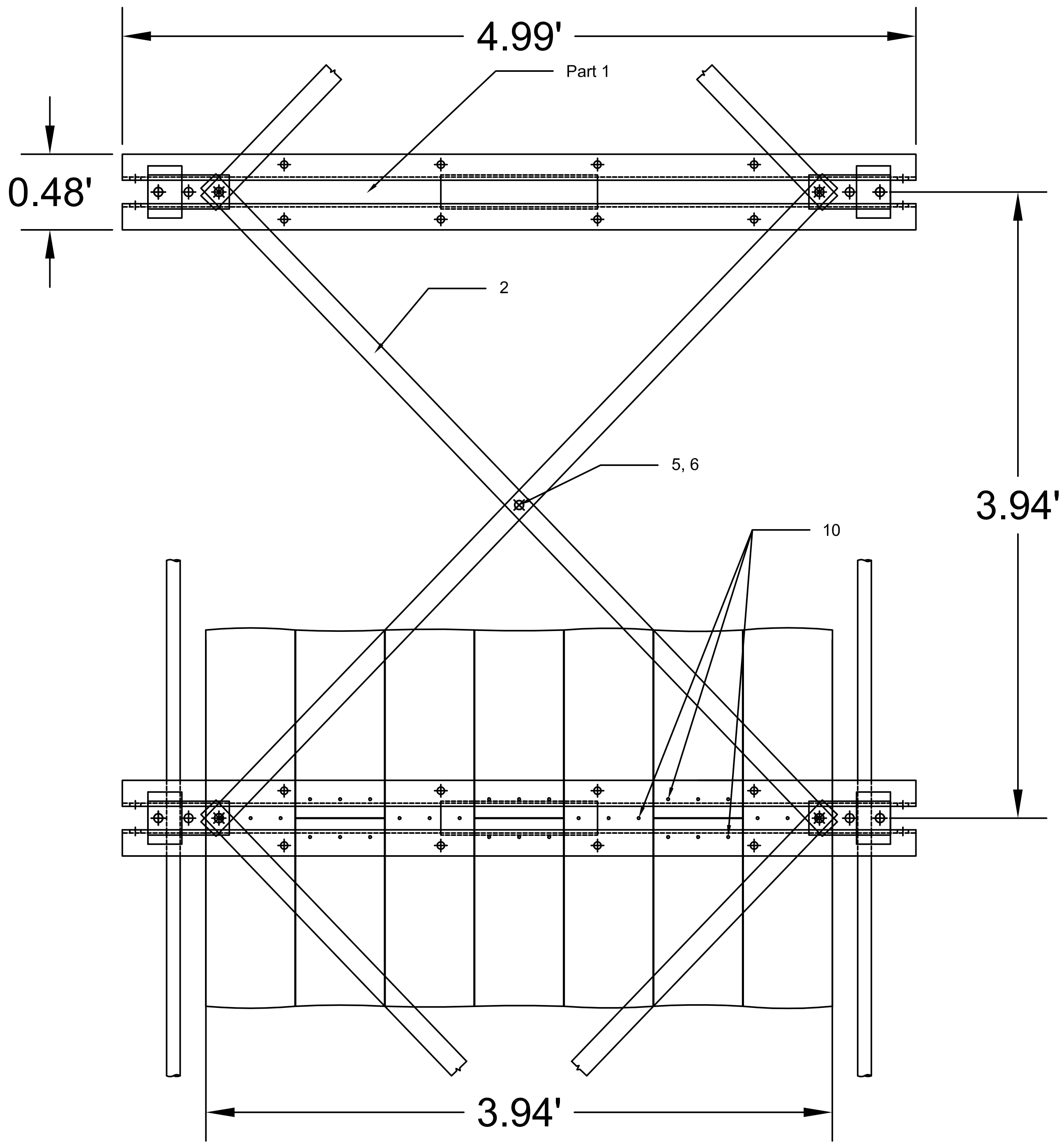
Drawing #
5 - *9*

Notes:
Sections & Plan View

36 SB Consulting

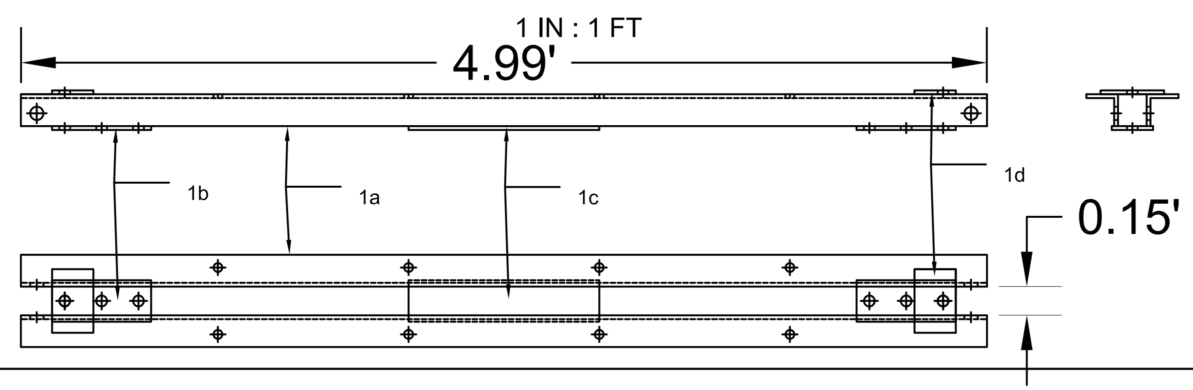
Walkway Design

1 IN : 1 FT



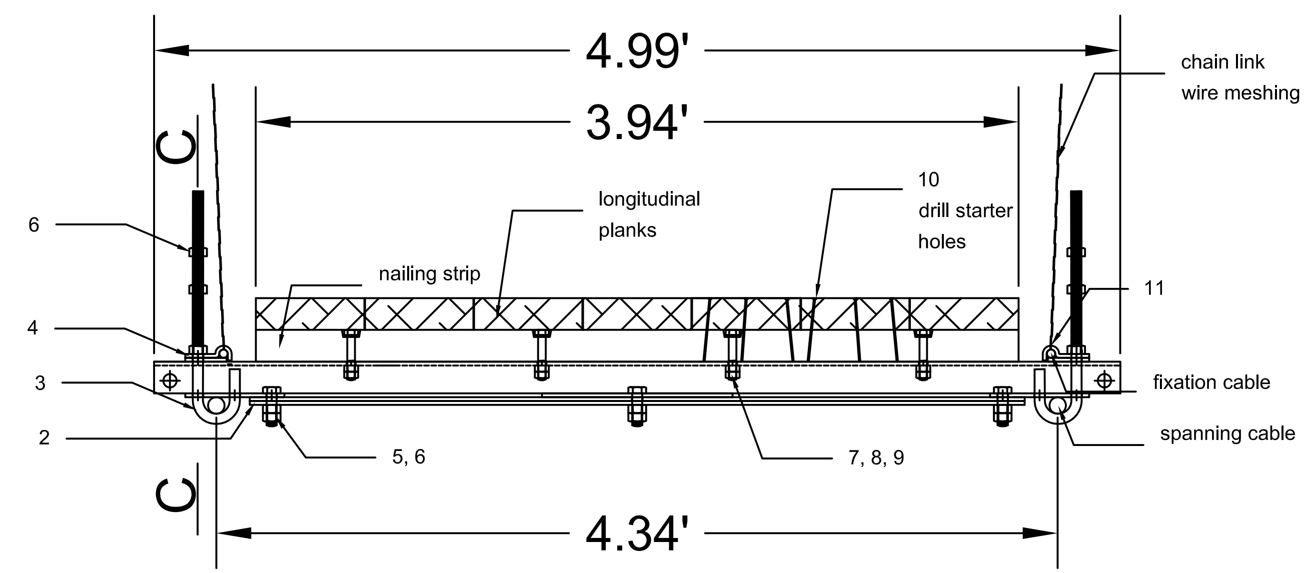
Welding Detail of Part 1

1 IN : 1 FT



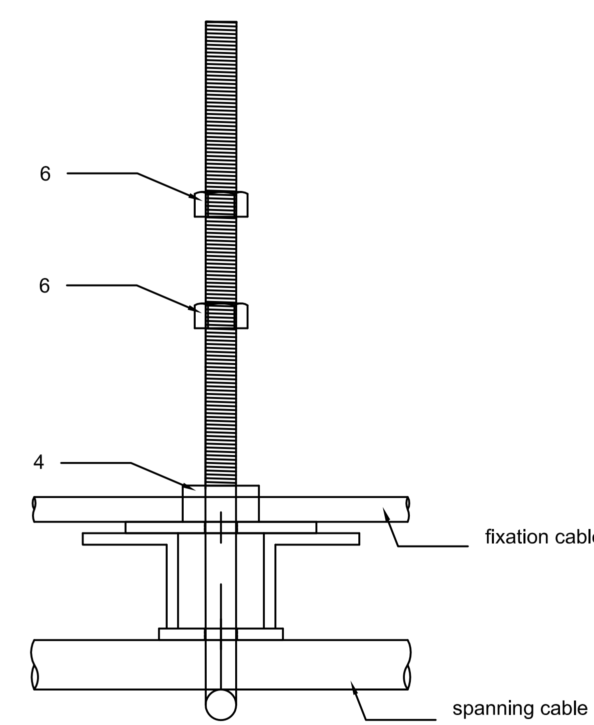
Walkway Design

1 IN : 1 FT



Section C-C

1 IN : 4 IN



Walkway Design

Drawn By: Deanna Larson

Drawing # 5-10

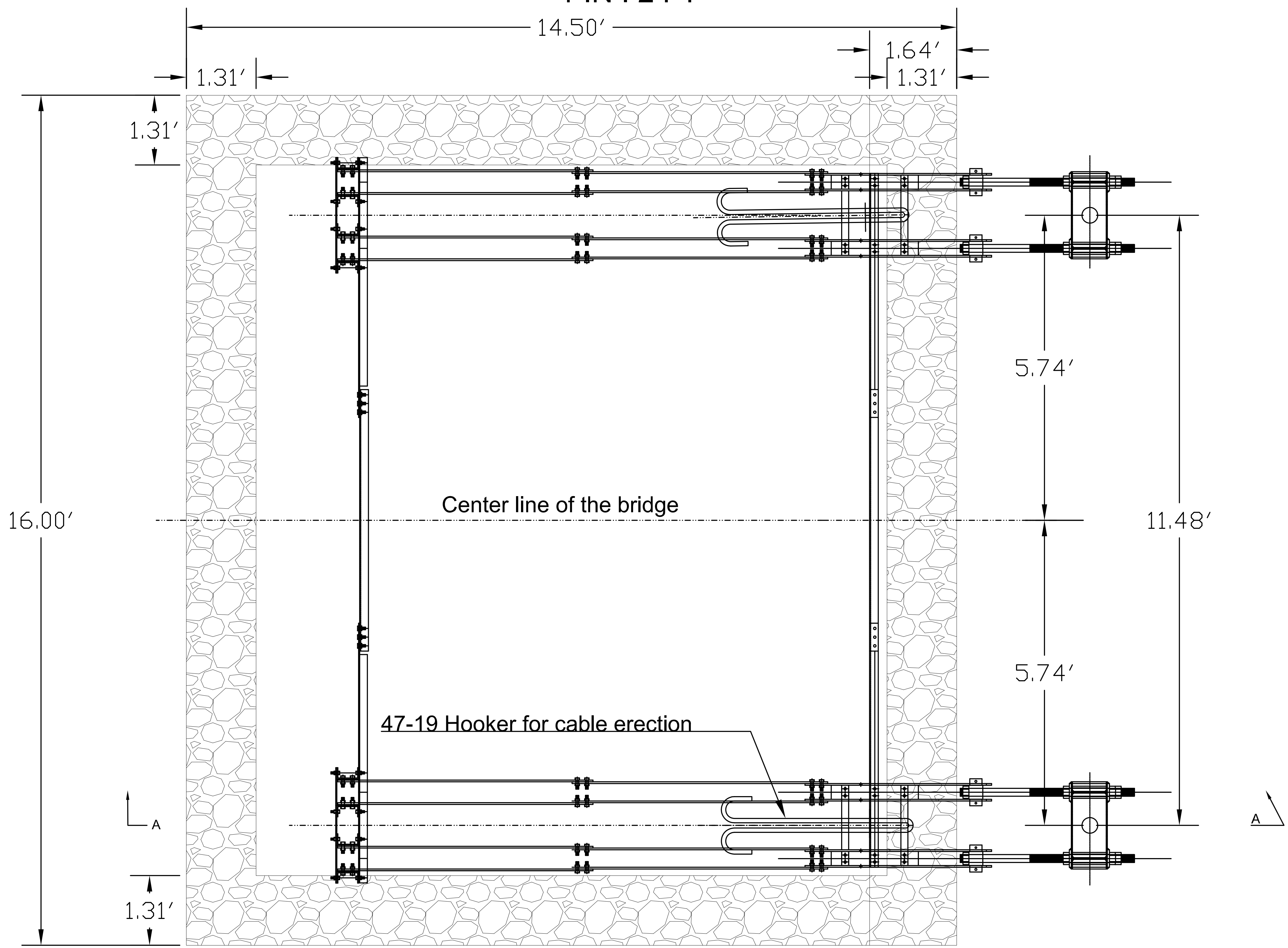
Notes:

See Appendix K for part details

36 SB Consulting

PLAN

1 IN : 2 FT



Main Cable Anchorage

Drawn By: Yingying Jin

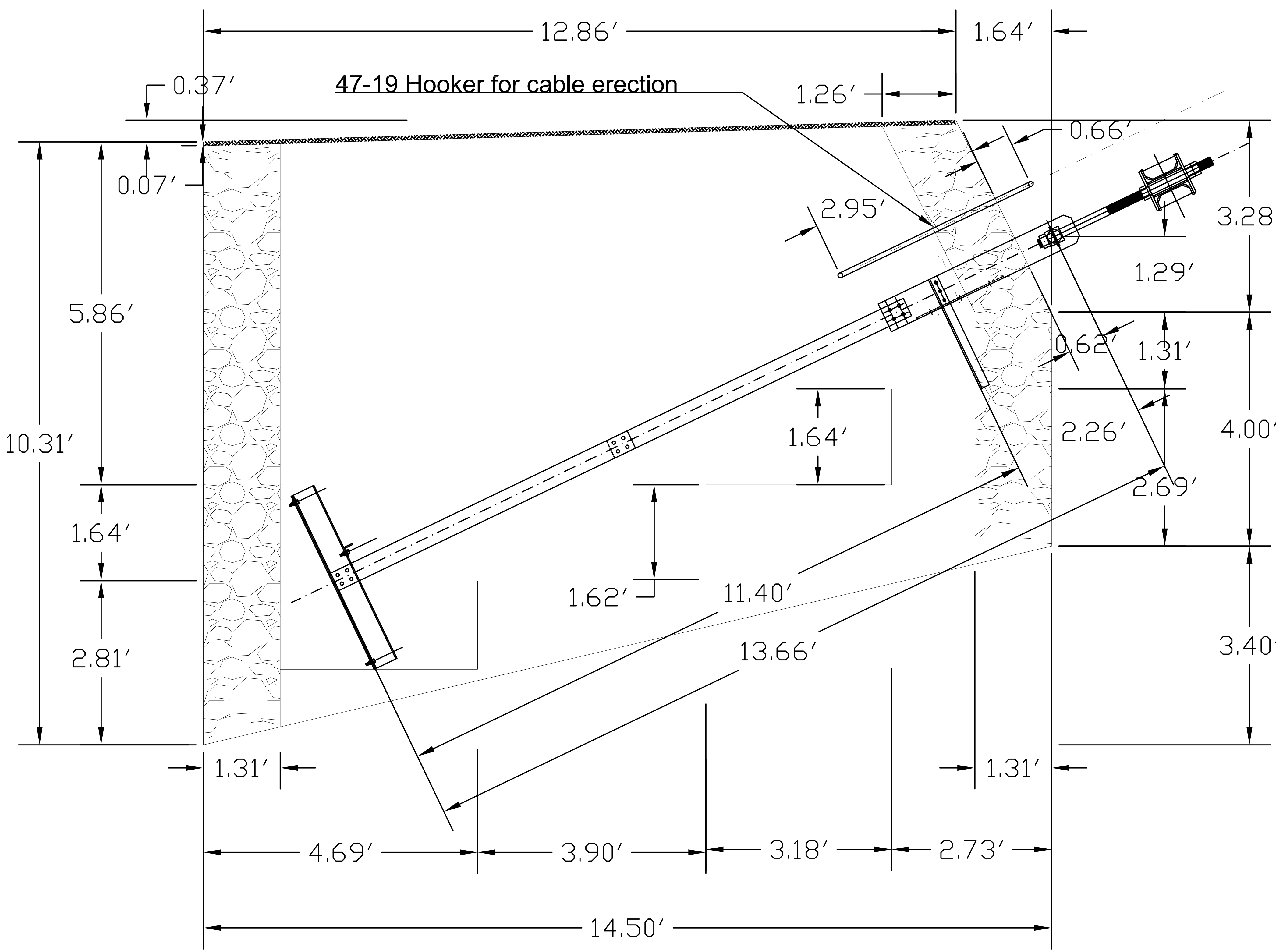
Drawing # 6-1

Notes: See Appendix K for part details

36 SB Consulting

Section A-A

1IN : 2 FT



Main Cable Anchorage

Drawn By: Yingying Jin

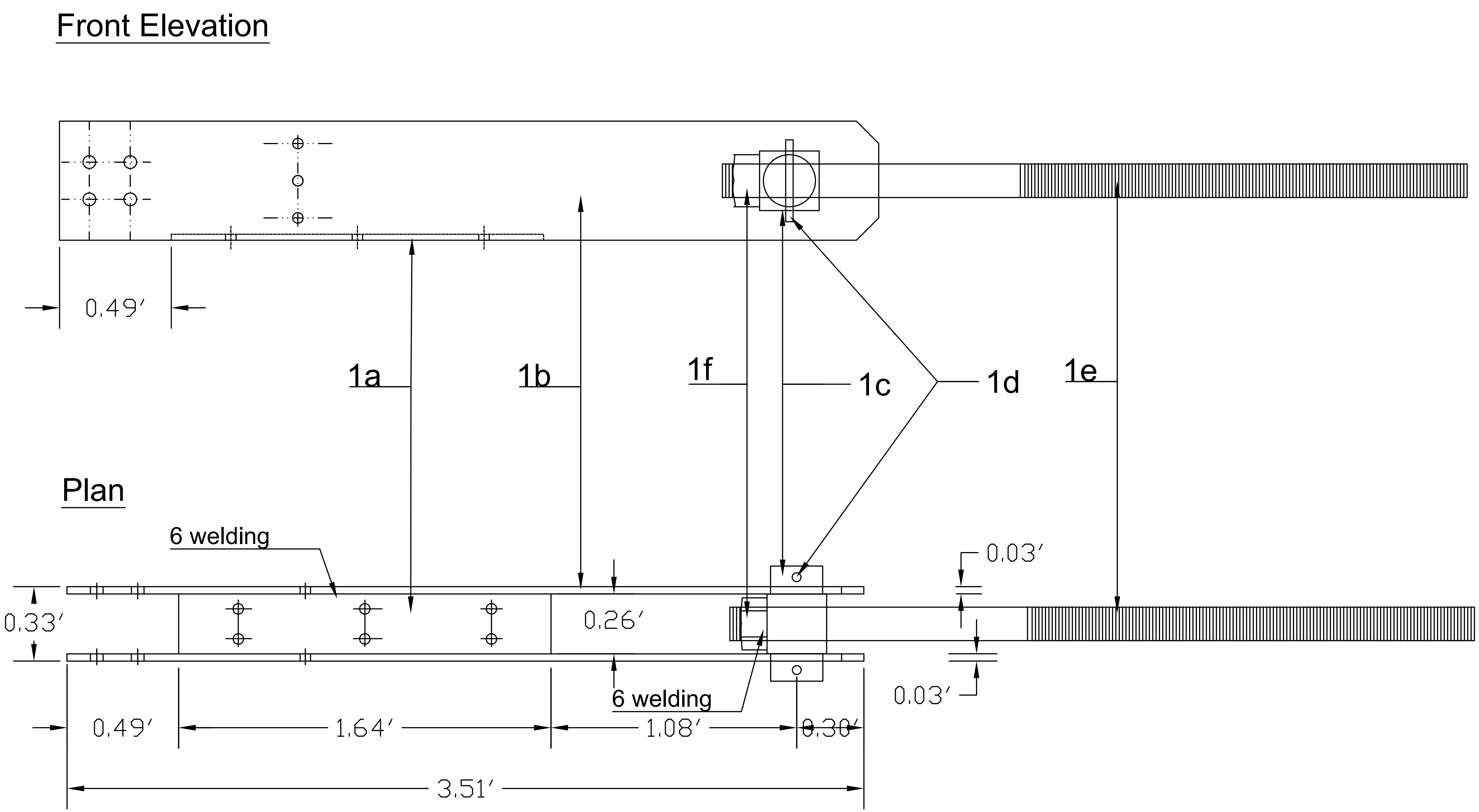
Drawing # 6-2

Notes: See Appendix K for part details

36 SB Consulting

Welding Detail of Part 1

1IN : 6IN



Main Cable Anchorage Welding parts

Drawn By: Yingying Jin

Drawing # 6-3

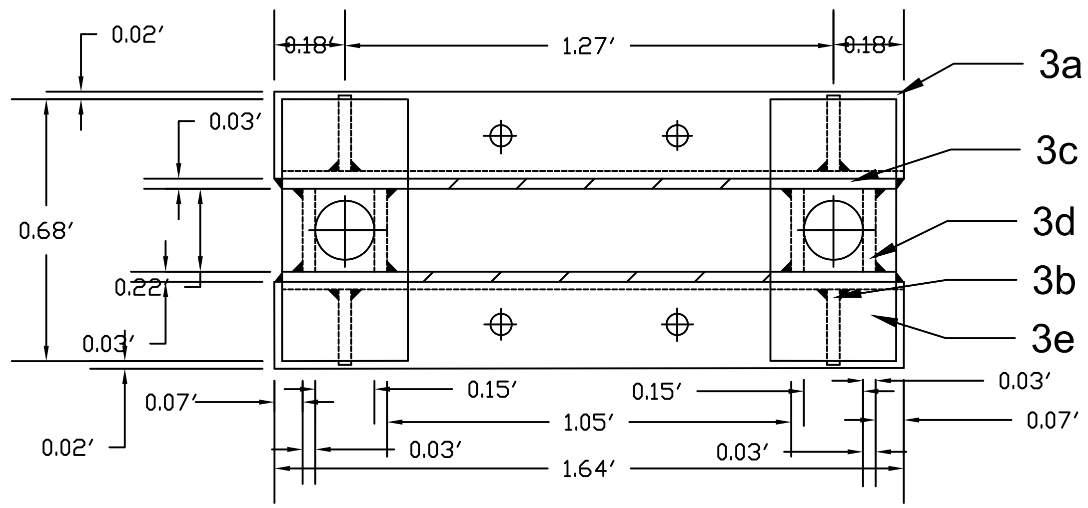
Notes: See Appendix K for part details

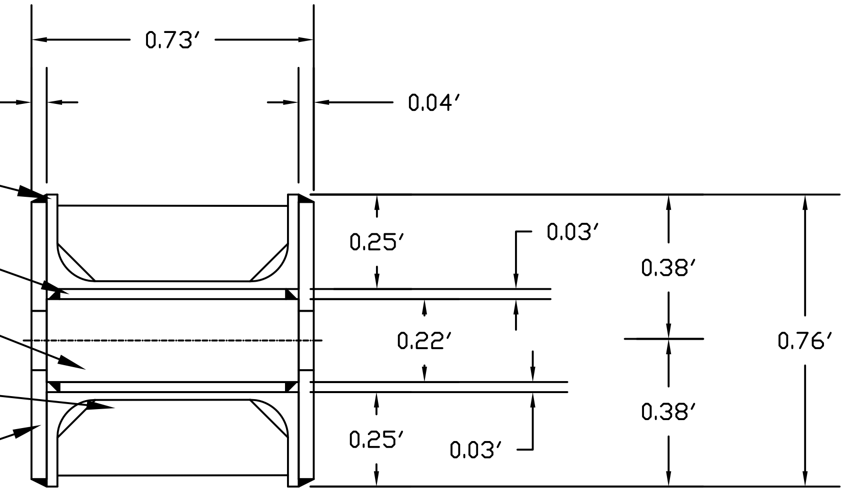
36 SB Consulting

Welding Details of Part3

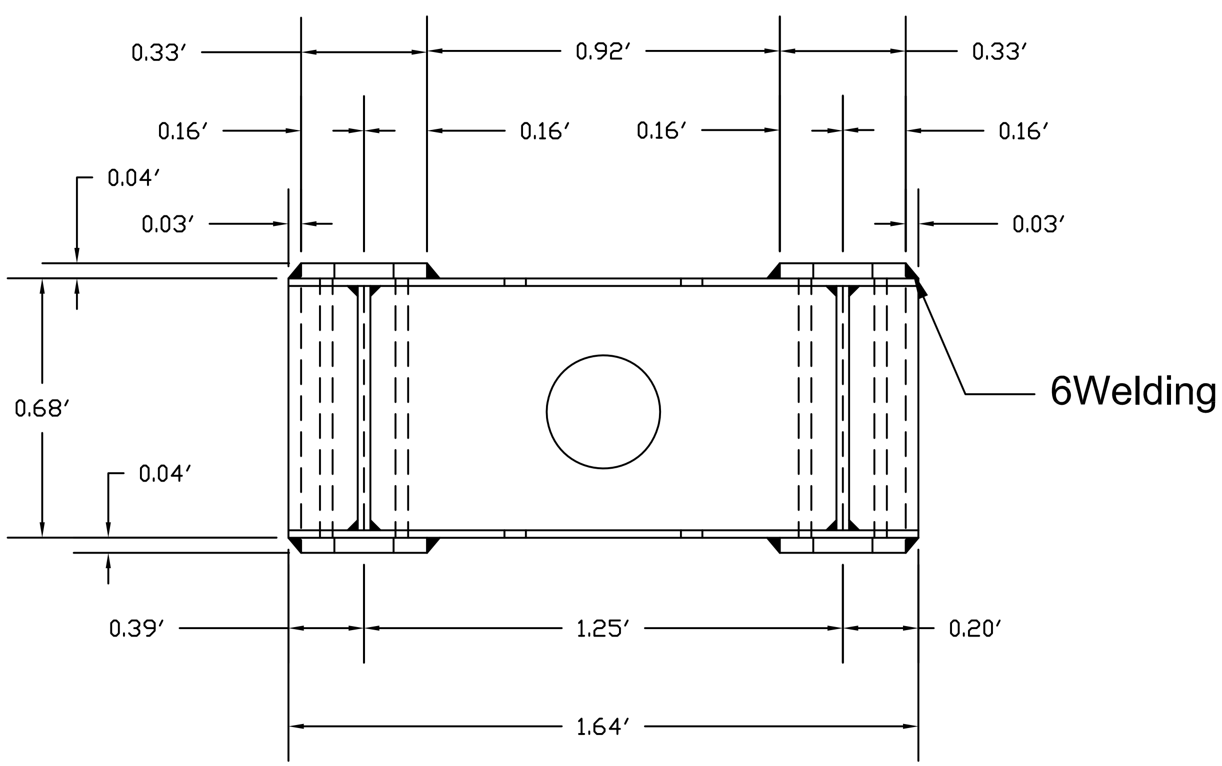
1IN : 6IN

Front Elevation





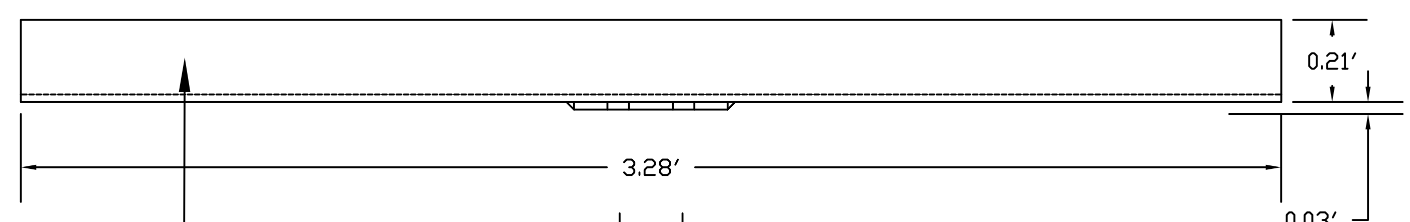
Plan



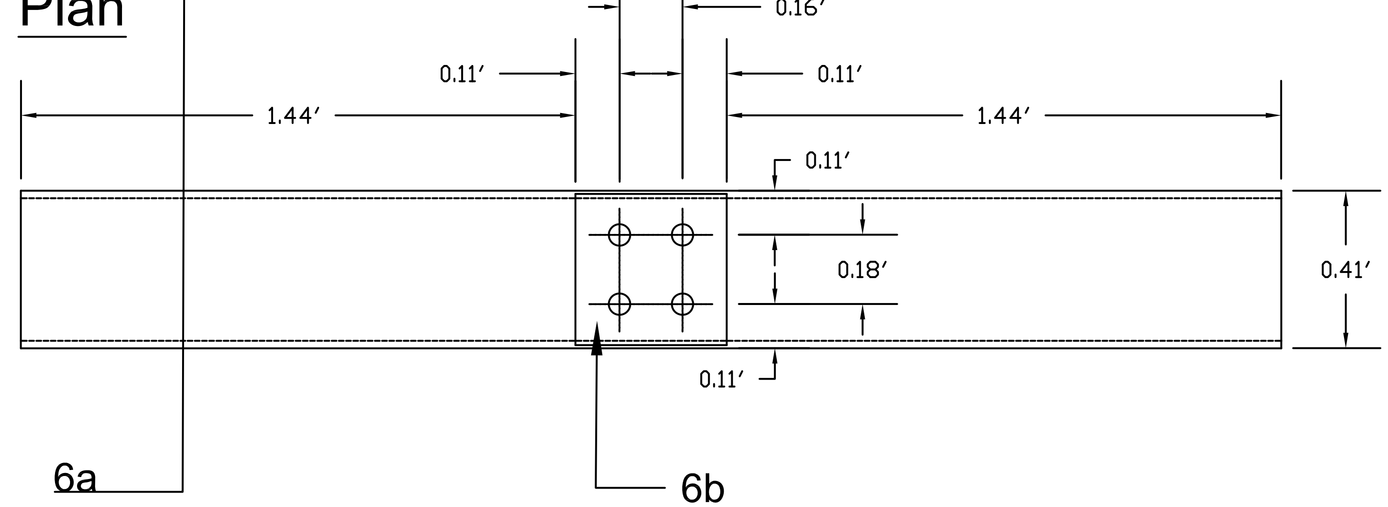
Welding Details of Part6

1IN : 6IN

Front Elevation



Plan



Main Cable Anchorage Welding parts

Drawn By: Yingying Jin

Drawing # 6-4

Notes: See Appendix K for part details

36 SB Consulting

APPENDIX K: SELECTED STEELPARTS LISTS FROM STANDARD DESIGN DRAWINGS

Suspenders

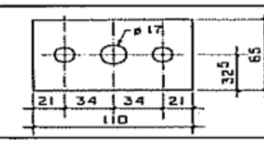
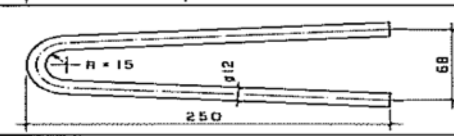
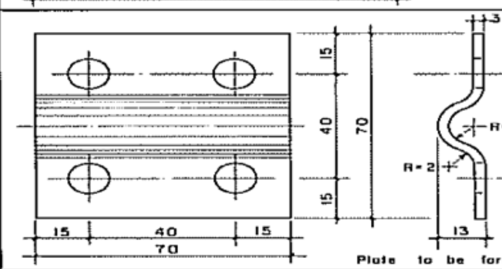
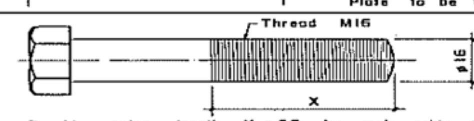
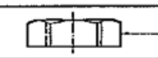
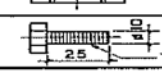
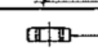
SUSPENDER LIST

STEELPART LIST

Suspender number		
Cable centre to centre distance c/c		
Total suspender length ℓ = c/c − 542 mm		
Length of extra piece ℓr		
Cutting length of extra piece ℓc = ℓr + 180		
Number of standard length pieces		
Suspender number		
Cable centre to centre distance c/c		
Total suspender length ℓ = c/c − 542 mm		
Length of extra piece ℓr		
Cutting length of extra piece ℓc = ℓr + 180		
Number of standard length pieces		
Suspender number		
Cable centre to centre distance c/c		
Total suspender length ℓ = c/c − 542 mm		
Length of extra piece ℓr		
Cutting length of extra piece ℓc = ℓr + 180		
Number of standard length pieces		
Suspender number		
Cable centre to centre distance c/c		
Total suspender length ℓ = c/c − 542 mm		
Length of extra piece ℓr		
Cutting length of extra piece ℓc = ℓr + 180		
Number of standard length pieces		
Suspender number		
Cable centre to centre distance c/c		
Total suspender length ℓ = c/c − 542 mm		
Length of extra piece ℓr		
Cutting length of extra piece ℓc = ℓr + 180		
Number of standard length pieces		
Suspender number		
Cable centre to centre distance c/c		
Total suspender length ℓ = c/c − 542 mm		
Length of extra piece ℓr		
Cutting length of extra piece ℓc = ℓr + 180		
Number of standard length pieces		
Suspender number		
Cable centre to centre distance c/c		
Total suspender length ℓ = c/c − 542 mm		
Length of extra piece ℓr		
Cutting length of extra piece ℓc = ℓr + 180		
Number of standard length pieces		
Suspender number		
Cable centre to centre distance c/c		
Total suspender length ℓ = c/c − 542 mm		
Length of extra piece ℓr		
Cutting length of extra piece ℓc = ℓr + 180		
Number of standard length pieces		
Suspender number		
Cable centre to centre distance c/c		
Total suspender length ℓ = c/c − 542 mm		
Length of extra piece ℓr		
Cutting length of extra piece ℓc = ℓr + 180		
Number of standard length pieces		
Suspender number		
Cable centre to centre distance c/c		
Total suspender length ℓ = c/c − 542 mm		
Length of extra piece ℓr		
Cutting length of extra piece ℓc = ℓr + 180		
Number of standard length pieces		
Suspender number		
Cable centre to centre distance c/c		
Total suspender length ℓ = c/c − 542 mm		
Length of extra piece ℓr		
Cutting length of extra piece ℓc = ℓr + 180		
Number of standard length pieces		
Suspender number		
Cable centre to centre distance c/c		
Total suspender length ℓ = c/c − 542 mm		
Length of extra piece ℓr		
Cutting length of extra piece ℓc = ℓr + 180		
Number of standard length pieces		
Suspender number		
Cable centre to centre distance c/c		
Total suspender length ℓ = c/c − 542 mm		
Length of extra piece ℓr		
Cutting length of extra piece ℓc = ℓr + 180		
Number of standard length pieces		
Suspender number		
Cable centre to centre distance c/c		
Total suspender length ℓ = c/c − 542 mm		
Length of extra piece ℓr		
Cutting length of extra piece ℓc = ℓr + 180		
Number of standard length pieces		
Suspender number		
Cable centre to centre distance c/c		
Total suspender length ℓ = c/c − 542 mm		
Length of extra piece ℓr		
Cutting length of extra piece ℓc = ℓr + 180		
Number of standard length pieces		

Total weight of Suspender rods :	....	kg
Total paint surface of Suspender rods :	....	m^2
Total number of Suspenders N :	....	

(Suspender number 1 : 2 pieces , all other Suspender numbers : 4 pieces)

Part no.		Section (mm)	Quantity	Working Drawing (Dimension in mm)	Length Single/pc mm	Length total m	Weight kg/pc	Weight total kg	Surface to be painted m^2/pc	Surface to be painted total m^2	Steel supplied by	Remarks
1	a	Flat 40/10 ℓ = 232	1	For working drawing of clamp for main cable of each diameter, see details. For a particular main cable diameter only one of the four alternatives is required.	232	0.23	1.132	1.132	0.029	0.029		For main cable ø26mm
		Flat 40/10 ℓ = 245	1		245	0.25	1.199	1.199	0.031	0.031		For main cable ø32mm
		Flat 40/10 ℓ = 254	1		254	0.25	1.245	1.245	0.032	0.032		For main cable ø36mm
		Flat 40/10 ℓ = 260	1		260	0.26	1.275	1.275	0.032	0.032		For main cable ø40mm
	b	Rod ø 12 of different lengths	See suspender list for number of suspenders and their lengths, weights and surface to be painted.									
	c	Flat 65/10 ℓ = 110	1	 2 holes ø 14, 1 hole ø 17	110	0.11	0.519	0.519	0.013	0.013		
	d	Rod ø 12 ℓ = 510	1		510	0.51	0.454	0.454	0.019	0.019		Weight of one welded unit = 0.973kg. Part nos. 1(a−d) to be welded together as shown in fabrication detail.
2		Plate 80/70/3	2	 Plate to be forged as shown.	—	—	0.123	0.246	0.010	0.020		
3		Hexagonal bolt M 16 x 90 IS 1363	1.05	 Provide extra length X = 50, for main cable ø 26 & ø 32mm. Use standard length X = 38, for main cable ø 36 & ø 40mm	—	—	0.169	0.177	Galvanized			5 % extra pcs. Ref: IS 1363−1967
4		Hexagonal nut M 16 IS 1363	2.1		—	—	0.032	0.067	Galvanized			5 % extra pcs. Ref: IS 1363−1967
5		Hexagonal screw M 10 x 25 IS 1363	4.2		—	—	0.025	0.105	Galvanized			5 % extra pcs. Ref: IS 1363−1967
6		Hexagonal nut M 10 IS 1363	4.2		—	—	0.008	0.034	Galvanized			5 % extra pcs. Ref: IS 1363−1967

TOTAL (1−6) EXCLUDING PART 1b

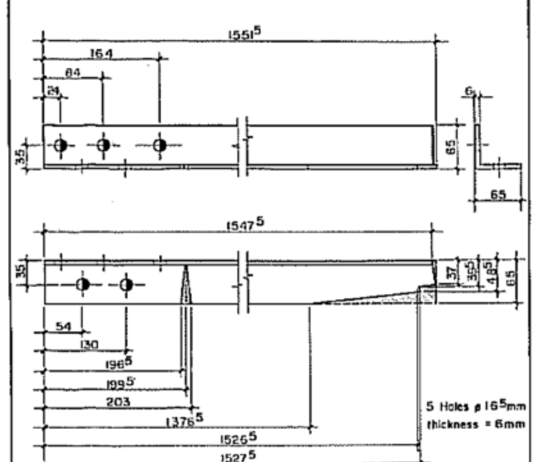
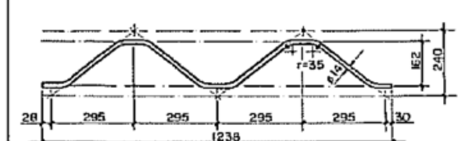
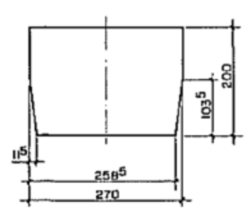
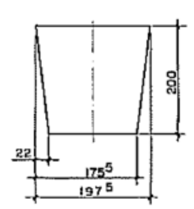
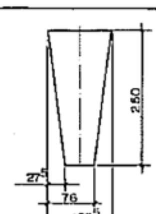
Main Cable Diameter	X (kg)	Y (m^2)
26 mm	2.734	0.081
32 mm	2.801	0.083
36 mm	2.847	0.084
40 mm	2.877	0.084

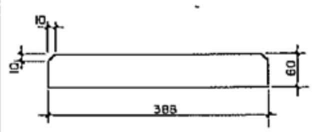
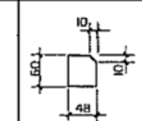
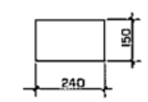
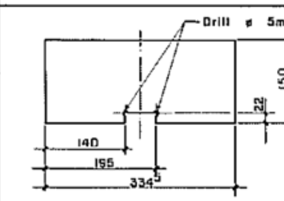
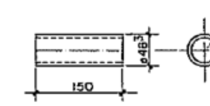
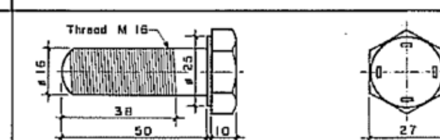
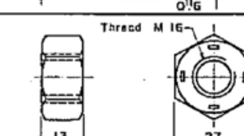
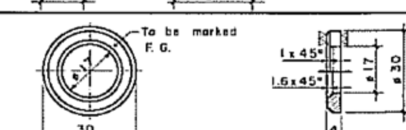
(Note : The quantities shown above are for each suspender)

WEIGHT	Total Weight of Suspender Rods from Suspender List	.... kg
	Total Weight of Other Parts = X x N kg	.... kg
	GRAND TOTAL	.... kg
SURFACE	Total Surface of Suspender Rods to be Painted from Suspender List	.... m^2
	Total Surface of Other Parts to be Painted = Y x N m^2	.... m^2
	GRAND TOTAL	.... m^2

Tower Base Element

STEELPART LIST

Part no		Section (mm)	Quantity	Working Drawing (Dimension in mm)	Length Single/pc mm	Length total m	Weight kg/pc	Weight total kg	Surface to be painted m²/pc	Surface to be painted total m²	Steel supplied by	Remarks
B-I	a	Angle 65 / 65 / 6 $l = 1551^5$	8	 5 Holes ø 16^5 mm thickness = 6mm; As shown – 4 nos ; Opposite hand – 4 nos	1551^5	12.41	8.83	70.64	0.40	3.20		Cut off the protion shown hatched in the drawing.
B-I	b	Rod ø 14 mm $l = 1461$	4		1461	5.84	1.77	7.08	0.06	0.24		
B-I	c	Plate 270 / 200 / 6	4	 thickness = 6 mm	–	–	2.49	9.96	0.11	0.44		
B-I	d	Plate 200 / 197^5 / 6	4	 thickness = 6mm	–	–	1.65	6.60	0.07	0.28		
B-I	e	Plate 250 / 103^5 / 6	4	 thickness = 6mm	–	–	0.89	3.56	0.04	0.16		

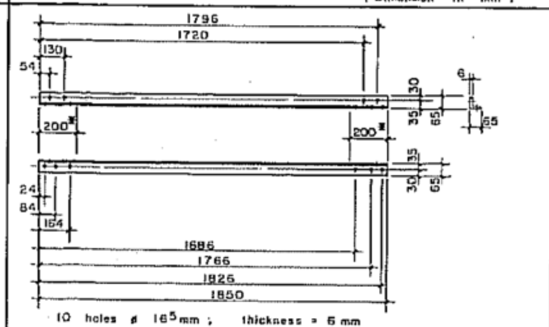
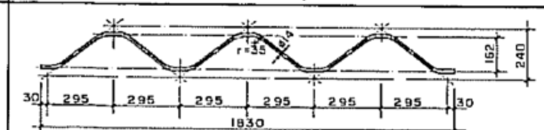
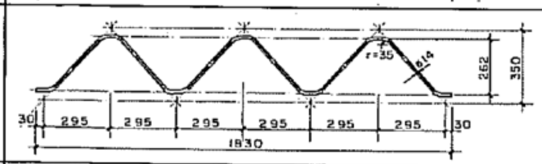
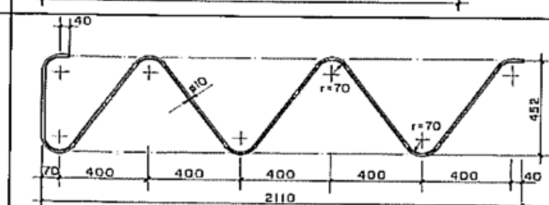
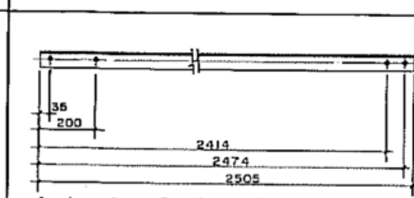
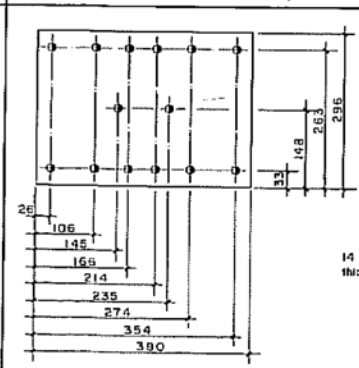
Part no		Section (mm)	Quantity	Working Drawing (Dimension in mm)	Length Single/pc mm	Length total m	Weight kg/pc	Weight total kg	Surface to be painted m²/pc	Surface to be painted total m²	Steel supplied by	Remarks
B-I	f	Plate 388 / 60 / 6	4	 thickness = 6mm	–	–	1.09	4.36	0.05	0.20		
B-I	g	Plate 60 / 48 / 6	8	 thickness = 6mm	–	–	0.13	1.04	0.01	0.08		
B-I	h	Plate 240 / 150 / 6	4	 thickness = 6mm	–	–	1.70	6.80	0.07	0.28		
B-I	i	Plate 334^5 / 150 / 14	2	 Drill ø 5mm; thickness = 14 mm	–	–	5.38	10.76	0.10	0.20		
B-I	j	IS heavy tube O.D. ø 48^3 $l = 150$	4		150	0.60	0.66	2.64	0.05	0.20		Part no B-I (a-j) to be welded together as shown in welding detail
B-2		Friction grip bolt M 16 x 50 IS 3757 – 8.8	42	 Thread M 16	–	–	0.12	5.04	Apply oil only			2 pcs. extra Ref: IS 3757 – 1972
B-3		Friction grip nut M 16 IS 6623-8	42	 Thread M 16	–	–	0.047	1.97	Apply oil only			2 pcs. extra Ref: IS 6623 – 1972
B-4		Washer 'A' 17 IS 6649	42	 To be marked F. G.	–	–	0.014	0.59	Apply oil only			2 pcs. extra Ref: IS 6649 – 1972
TOTAL (B-I to B-4)								131.04 kg		5.28 m²		

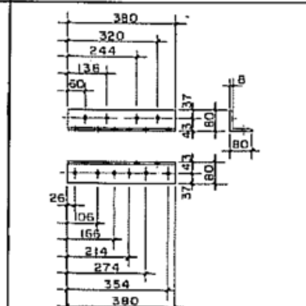
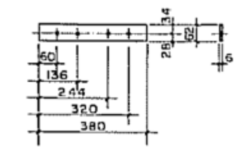
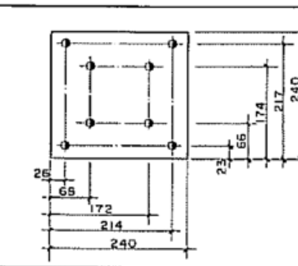
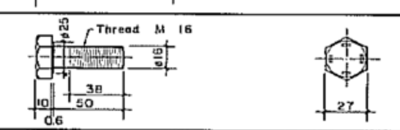
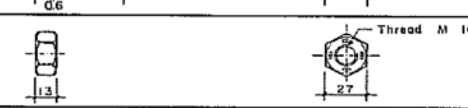
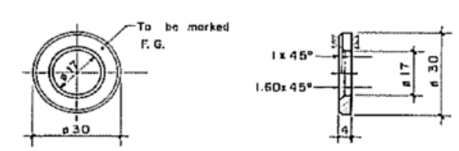
TRANSPORT UNIT

Weight of part B-I = 61.72 kg

Tower Intermediate Element

STEELPART LIST

Part no		Section (mm)	Quantity	Working Drawing (Dimension in mm)	Length Single/pc mm	Length Total m	Weight kg/pc	Weight Total kg	Surface to be Painted m²/pc	Surface to be Painted Total m²	Steel supplied by	Remarks
I-1	a	Angle 65/65/6 ℓ = 1850	16	 10 holes ø 16^{5}mm ; thickness = 6 mm	1850	29.60	10.63	170.08	0.48	7.68		※ On the end of angles the corner to be ground off (for a length of 200 mm) as shown above. ø 14mm rods to be bent as shown.
	b	Rod ø 14 mm ℓ = 2164	8		2164	17.31	2.62	20.96	0.10	0.80		Part nos. I-1 (a, b, c) to be welded together as shown in welding detail.
	c	Rod ø 14 mm ℓ = 2536	8		2536	20.29	3.07	24.56	0.11	0.88		
I-2	a	Rod ø 10mm ℓ = 3709	4		3709	14.84	2.30	9.20	0.12	0.48		Part no I-2 (a) ø 10 mm rod to be bent as shown.
	b	Angle 60/40/6 ℓ = 2505	8	 6 holes ø 16^{5}mm thickness = 6 mm. As shown 4 pcs, Opposite hand 4 pcs.	2505	20.04	10.96	87.68	0.50	4.00		Part nos. I-2 (a, b) to be welded together as shown in welding detail.
I-3		Plate 380/296/6	4	 14 holes ø 16^{5}mm thickness = 6mm	–	–	5.16	20.64	0.23	0.92		

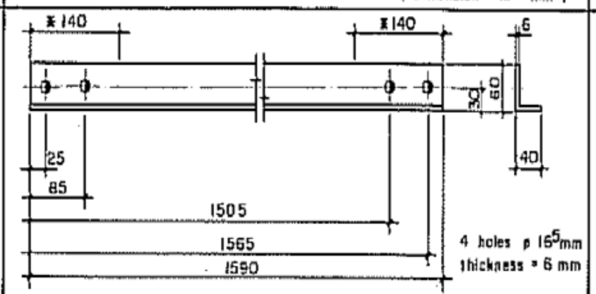
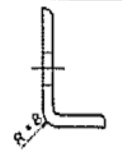
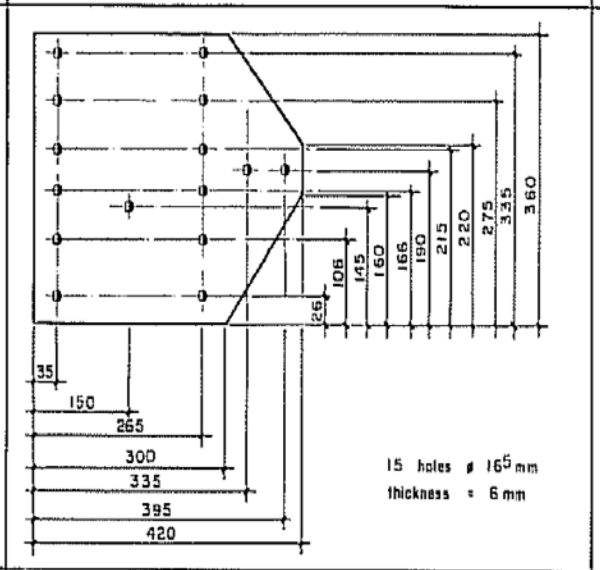
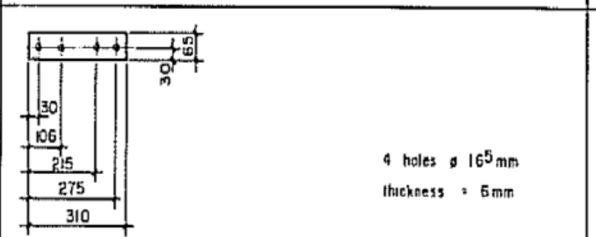
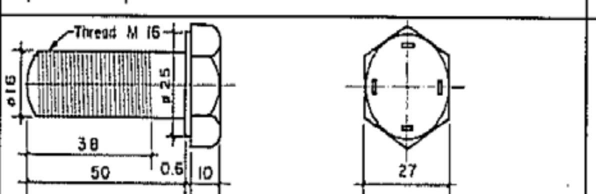
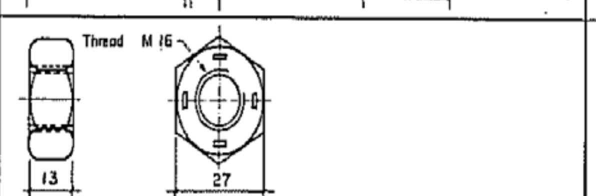
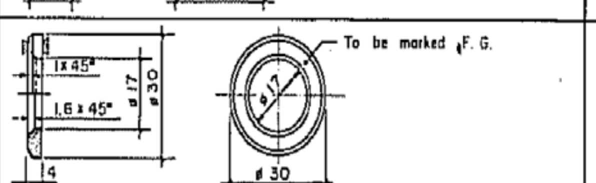
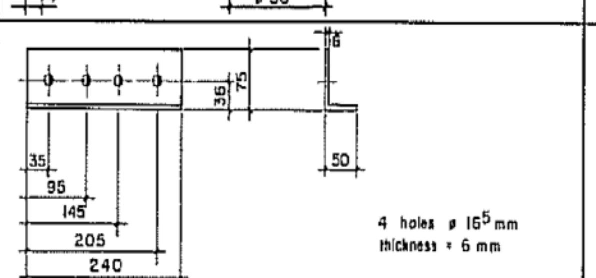
Part no	Section (mm)	Quantity	Working Drawing (Dimension in mm)	Length Single/pc mm	Length Total m	Weight kg/pc	Weight Total kg	Surface to be painted m²/pc	Surface to be painted Total m²	Steel supplied by	Remarks
I-4	Angle 80/80/8 ℓ = 380	8	 10 holes ø 16^{5}mm thickness = 8mm	380	3.04	3.51	28.08	0.12	0.96		
I-5	Plate 380/82/6	8	 4 holes ø 16^{5}mm thickness = 6mm	–	–	1.07	8.56	0.05	0.40		
I-6	Plate 240/240/6	2	 8 holes ø 16^{5}mm thickness = 6mm	–	–	2.63	5.26	0.12	0.24		
I-7	Friction grip bolt M 16 x 50 IS 3757 – 8.8	193	 Thread M 16	–	–	0.12	23.16	Apply oil only			9 pcs. extra Ref: IS 3757 – 1972
I-8	Friction grip nut M 16 IS 6623-8	193	 Thread M 16	–	–	0.047	9.07	Apply oil only			9 pcs. extra Ref: IS 6623-1972
I-9	Washer 'A' 17 IS 6649	193	 To be marked F.G.	–	–	0.014	2.70	Apply oil only			9 pcs. extra Ref: IS 6649-1972
TOTAL (I-1 to I-9)							409.95 kg	16.36 m²			

TRANSPORT UNIT

Weight of part I-1 = 53.90 kg
Weight of part I-2 = 24.22 kg

Tower Top Element

STEELPART LIST

Part no		Section (mm)	Quantity	Working Drawing (Dimension in mm)	Length single/pc mm	Length total m	Weight kg/pc	Weight total kg	Surface to be painted m²/pc	Surface to be painted total m²	Steel supplied by	Remarks
T-1	a	Angle 60/40/6 l = 1590	4		1590	6.36	6.96	27.84	0.32	1.28		 ✱ The corners at the end of angles to be ground off (for a length of 140mm) as shown above.
T-1	b	Rod ø 10mm l = 2536	2	Rod ø 10 to be bent as shown in welding detail	2536	5.07	1.57	3.14	0.08	0.16		Part nos T-1 (a,b) to be welded together as shown in welding detail
T-2		Plate 420/360/6	4		–	–	6.12	24.48	0.27	1.08		
T-3		Plate 310/65/6	8		–	–	0.91	7.28	0.04	0.32		
T-4		Friction grip bolt M 16 × 50 IS 3757 – 8.8	60		–	–	0.12	7.20	Apply oil only			4 pcs extra Ref : IS 3757 – 1972
T-5		Friction grip nut M 16 IS 6623-8	60		–	–	0.047	2.82	Apply oil only			4 pcs. extra Ref : IS 6623 – 1972
T-6		Washer 'A' 17 IS 6649	60		–	–	0.014	0.84	Apply oil only			4 pcs. extra Ref : IS 6649 – 1972
T-7		Angle 75/50/6 l = 240	2		240	0.48	1.30	2.60	0.06	0.12		
TOTAL (T-1 to T-7)								76.20 kg		2.96 m²		

TRANSPORT UNIT

Weight of part T-1 = 15.49 kg

Tower Saddle

STEELPART LIST S-1

Part no	Section (mm)	Quantity	Working Drawing (Dimension in mm)	Length single/pc mm	Length total m	Weight kg/pc	Weight total kg	Surface to be painted m²/pc	Surface to be painted total m²	Steel supplied by	Remarks
a	Plate 170/65/6	8	2 holes ø 16.5 mm thickness = 6 mm	–	–	0.47	3.76	0.02	0.16		
b	Plate 288/170/6	4	6 holes ø 16.5 mm thickness = 6 mm	–	–	2.25	9.00	0.10	0.40		
c	Plate 388/202/8	4	thickness = 8 mm	–	–	4.35	17.40	0.07	0.28		
d	Plate 144/144/6	2	thickness = 6 mm	–	–	0.71	1.42	–	–		
e	Plate 388/144/6	2	Slot 6 wide; thickness = 6 mm	–	–	2.61	5.22	0.06	0.12		
f	Plate 391/90/8	4	thickness = 8 mm	–	–	.59	2.36	0.20	0.06		
g	Plate 430/170/12	2	4 holes ø 21 mm thickness = 12 mm	–	–	5.06	10.12	0.08	0.16		
h	Plate 120/50/14	4	2 holes ø 21mm thickness = 13 mm	–	–	0.46	1.84	0.01	0.04		

Part no	Section (mm)	Quantity	Working Drawing (Dimension in mm)	Length single/pc mm	Length total m	Weight kg/pc	Weight total kg	Surface to be painted m²/pc	Surface to be painted total m²	Steel supplied by	Remarks
i	Plate 122/100/10	8	thickness = 10 mm; Hole ø 25mm +.033 −.000	–	–	0.81	6.48	0.02	0.16		Part No. S-1 (a-i) to be welded together as shown alongside
S-2	Plate 170/120/20	2	Shape or mill 3 down; 4 holes ø 21mm thickness = 20mm	–	–	2.91	5.82	0.05	0.10		
S-3	Friction grip bolt M 20×120 IS 3757-8.8	9	Hole ø 4 mm; Thread M 20	–	–	0.38	3.42	Apply oil only			1 pc. extra Ref: IS 3757-197
S-4	Friction grip nut M 20 IS 6623-8	9	Thread M 20	–	–	0.079	0.71	Apply oil only			1 pc. extra Ref: IS 6623-1972
S-5	Washer 'A' 21 IS 6649	9	To be marked F.G.	–	–	0.021	0.19	Apply oil only			1 pc. extra Ref: IS 6649-1972
S-6	Cotter pin	9		–	–	0.003	0.03	Apply oil only			1 pc. extra

TOTAL (S-1 to S-6) 67.77 kg 1.50 m²

TRANSPORT UNIT

Weight of part S-1 = 28.60 k

Foundation

STEELPART LIST

Part no.		Section (mm)	Quantity	Working Drawing (Dimension in mm)	Length Single/pc mm	Length total m	Weight kg/pc	Weight total kg	Surface to be painted m²/pc	Surface to be painted total m²	Steel supplied by	Remarks
1	a	Angle 80/80/8 l = 400	2	Slot 33 wide; 2 holes ø 17 ; 1 Slot 33 x 300	400	0.80	3.20	6.40	0.11	0.22		
	b	Flat 40/6 l = 1200	2		1200	2.40	2.26	4.52	0.11	0.22		Weight of one welded unit = 19.12 kg.
	c	Rod ø 32 l = 1270	1		1270	1.27	8.01	8.01	0.13	0.13		
	d	Plate ø 60 thickness = 6	2		–	–	0.093	0.19	–	–		Part nos. 1 (a–d) to be welded together as shown in welding detail.
2		Rod ø 16 l = 630	4	Thread M 16	630	2.52	1.00	4.00	–	–		
3		Rod ø 16 l = 155	14	Thread M 16; Rod to be bent as shown after threading.	155	2.17	0.24	3.36	0.01	0.14		
4	a	Plate 150/110/6	12	1 hole ø 17 thickness = 6	–	–	0.77	9.24	0.04	0.32 (4 pcs. not painted)		Difficult part for transportation
	b	Plate 230/200/6	4		–	–	2.17	6.68	–	–		
	c	Channel ISMC 75–2450	4	Surface to be painted; 1 hole ø 25; 4 holes ø 9	2450	9.80	16.63	66.52	0.41	1.64 (Partially painted)		
	d	Rod ø 24 l = 150	4		150	0.60	0.53	2.12	0.01	0.04		
	e	Open thimble	4	Thimble to ISI standard for cable ø 13 mm	–	–	0.12	0.48	Galvanized			Weight of one welded unit = 44,02 kg.
	f	Plate 100/60/6	4	1 hole ø 25 thickness = 6	–	–	0.25	1.00	0.01	0.04		Part nos. 4 (a–f) to be welded together as shown in welding detail.
5		Channel ISMC 200–690	2	2 holes ø 52	690	1.38	15.11	30.22	–	–		
6	a	Rod ø 50 l = 985	4	Thread M48; THREAD DATA: Major Dia. = 48.000 Minor Dia. = 41.866 Pitch = 5	985	3.94	14.39	57.56	–	–		Weight of one welded unit = 14.85 kg.
	b	Plate 70/70/20	4	1 hole ø 50⁺ thickness = 20	–	–	0.46	1.84	–	–		Part nos. 6 (a–b) to be welded together as shown in welding detail.
7		Hexagonal nut M 48	17	Thread M 48; THREAD DATA: Major Dia. = 48.000 Minor Dia. = 42.587 Pitch = 5	–	–	0.97	16.49	Galvanized			1 pc. extra.
8		Plate ø 90 thickness = 16	5	1 hole ø 52 thickness = 16	–	–	0.53	2.65	–	–		1 pc. extra.
9	a	Plate 680/250/32	2	2 holes ø 52 thickness = 32	–	–	41.64	83.28	0.39	0.78		Weight of one welded unit = 45.19 kg.
	b	Plate 480/30/32	2	Shape or mill on both sides to get thickness = 30	–	–	3.39	6.78	0.04	0.08		
	c	Square bar 20 l = 50	2		50	0.10	0.16	0.32	–	–		Part nos. 9 (a–c) to be welded together as shown in welding detail.
10		Rod ø 16 l = 212	5	Thread M 16; Rod to be bent as shown after threading.	–	–	0.32	1.60	–	–		1 pc. extra.
11	a	Channel ISMC 125–1000	4	4 holes ø 17	1000	4.00	12.66	50.64	–	–		
	b	Flat 40/6 l = 383	4		383	1.53	0.72	2.88	–	–		Weight of one welded unit = 45.08 kg.
	c	Plate 600/200/10	4	2 holes ø 46 thickness = 10	–	–	9.16	36.64	–	–		Part nos. 11 (a–c) to be welded together as shown in welding detail.
12	a	Rod ø 45 l = 2340	4	Thread M42; THREAD DATA: Major Dia. = 42.000 Minor Dia. = 36.479 Pitch = 4.5	2340	9.36	27.13	108.52	–	–		Difficult part for transportation. Weight of one welded unit = 27.34 kg.
	b	Plate ø 80 thickness = 8	4	1 hole ø 46 thickness = 8	–	–	0.21	0.84	–	–		Part nos. 12 (a–b) to be welded together as shown in welding detail.
13		Angle 65/65/6 l = 410	4	3 holes ø 17 thickness = 6	410	1.64	2.35	9.40	–	–		
14		Rod ø 16 l = 199	5	Thread M 16; Rod to be bent as shown after threading.	199	1.00	0.30	1.50	–	–		1 pc. extra.
15		Hexagonal nut M 42	21	Thread M 42; THREAD DATA: Major Dia. = 42.000 Minor Dia. = 37.129 Pitch = 4.5	–	–	0.65	13.65	–	–		1 pc. extra.
16		Washer ø 46 thickness = 10	5		–	–	0.26	1.30	–	–		1 pc. extra.
17		Rod ø 90 l = 180	2	2 holes ø 10	180	0.36	8.88	17.76	Apply grease only			
18		Split pin ø 8 l = 150	5		–	–	0.06	0.30	Bright steel			1 pc. extra.

Foundation (continued)

Part no.		Section (mm)	Quantity	Working Drawing (Dimension in mm)	Length Single/pc mm	Length total m	Weight kg/pc	Weight total kg	Surface to be painted m²/pc	Surface to be painted total m²	Steel supplied by	Remarks
19	a	Channel ISMC 200-500	4	1 hole ø 90 $^{+0.087}_{-0.00}$	500	2.00	10.80	43.20	0.25	1.00		Weight of one welded unit = 45.86kg.
	b	Plate 183/60/10	8	Slope to suit channel flange (See welding detail) Grind as necessary	–	–	0.79	6.32	0.03	0.24		
	c	Plate 480/180/8	4	1 hole ø 90 $^{+0.087}_{-0.00}$ Bore after welding to part no 19 a. thickness = 8	–	–	5.03	20.12	0.08	0.32		
	d	Plate 200/66/10	8	thickness = 10	–	–	1.04	8.32	0.03	0.24		
	e	Plate 220/100/12	8	1 hole ø 47 thickness = 12	–	–	1.72	13.76	0.03	0.24		Part nos. 19 (a-e) to be welded together as shown in welding detail.
20	a	Rod ø 25 ℓ = 1950	6	Surface to be painted. R = 15 (inside) R = 50 The rod to be bent to form the hook as shown.	1950	11.70	7.51	45.06	0.02 (Partly painted)	0.12		
	b	Plate 200/30/10	6	Surface to be painted thickness = 10	–	–	0.47	2.82	Negligible			
	c	Rod ø 25 ℓ = 576	12	1. No thinning of section during bending allowed 2. Change of radius of curvature to be gradual	576	6.91	2.22	26.64	0.05	0.60		
	d	Plate 130/65/25 Left threaded	6	SECTION A-A Thread M 24 THREAD DATA: Major Dia. = 24.000 Minor Dia. = 20.752 Pitch = 3 2 holes ø 26 thickness = 25	–	–	1.37	8.22	0.02	0.12		Weight of one welded unit = 17.01kg.
		Right threaded	6		–	–	1.37	8.22	0.02	0.12		
	e	Rod ø 25 ℓ = 445	6	R. H. thread L. H. thread THREAD DATA: Major Dia. = 24.000 Minor Dia. = 20.320 Pitch = 3 2 holes ø 6 rod ø 25	445	2.67	1.35	8.10	–	–		One right threaded nut tightned to part 20e and welded.
	f	Hexagonal nut M24 Right threaded	12	Thread M 24 THREAD DATA: Major Dia. = 24.000 Minor Dia. = 20.752 Pitch = 3	–	–	0.12	1.44	Galvanized			
		Left threaded	6		–	–	0.12	0.72	Galvanized			
	g	Rod ø 5 ℓ = 40	12		40	4.80	0.01	0.12	–	–		Part nos. 20 (a-h) to be assembled together as shown in assembly and welding detail.
	h	Open thimble	6	Thimble to ISI standard for cable ø 13 mm	–	–	0.12	0.72	Galvanized			
21		Rod ø 16 ℓ = 147	13	R = 12.5 Thread M 16 Rod to be bent as shown after threading.	147	1.91	0.22	2.86	–	–		1 pc. extra.
22		Flat 40/6 ℓ = 500	4	6 holes ø 17 thickness = 6	500	2.00	0.88	3.52	–	–		
23		Angle 50/50/6 ℓ = 1365	2	6 holes ø 17 ; thickness = 6 As shown – 1 pc. ; Opposite hand – 1 pc.	1365	2.73	6.08	12.16	–	–	/	

Cable ø mm	Bulldog grips required per cable	Weight (kg/pc) Thimble	Weight (kg/pc) B. grip	Gap 'G'
36	7	2.75	1.85	210
40	8	3.20	2.40	240

*

Part no.		Section (mm)	Quantity	Working Drawing (Dimension in mm)	Length Single/pc mm	Length total m	Weight kg/pc	Weight total kg	Surface to be painted m²/pc	Surface to be painted total m²	Steel supplied by	Remarks
24		Angle 50/50/6 ℓ = 2188	1	8 holes ø 17	2188	2.19	9.72	9.72	–	–		Difficult part for transportatation
25		Flat 40/6 ℓ = 540	1	4 holes ø 17 thickness = 6	540	0.54	0.97	0.97	–	–		
26	a	Rod ø 16 ℓ = 976	2	R = 25 Thread M 16 Rod to be bent as shown after threading	976	1.95	1.54	3.08	0.05	0.10		Weight of one welded unit = 1.80 kg. Part nos. 26 (a-b) to be welded together as shown in welding detail.
	b	Washer ø 18 IS : 6610	4		–	–	0.028	0.11	Galvanized			Ref: IS 6610 – 1972.
27		Hexagonal nut M16 IS 1363	82	Thread M 16	–	–	0.032	2.62	Galvanized			4 pcs. extra Ref: IS 1363 – 1967.
28		Washer ø 18 IS 6610	15		–	–	0.028	0.42	Galvanized			1 pc. extra. Ref: IS 6610 – 1972.
29		Hexagonal screw M 16 x 40 IS 1363	13	Thread M 16	–	–	0.095	1.24	Galvanized			1 pc. extra. Ref: IS 1363 – 1967.
30		Rod ø 20 ℓ = 1723	2	R = 15 (inside) R = 40 Surface to be painted. The rod to be bent to form the hook as shown.	1723	3.45	4.25	8.50	0.01 (Partly painted)	0.02		Used as erection hook (for tirfor machine)
31		Bulldog grip	31	M. S. forged bulldog grip to ISI standard for cable ø 13mm	–	–	0.28	8.68	Galvanized			1 pc. extra. Ref: IS 2361 – 1970.
32		Open thimble	2	Thimble to ISI standard for cable ø .... mm	–	–	.... *	....	Galvanized			Ref: IS 2315 – 1978.
33		Bulldog grip	.... *	M.S. forged bulldog grip to ISI standard for cable ø .... mm	–	–	.... *	....	Galvanized			Ref: IS 2361 – 1970.
34		Rod ø 12 ℓ = 3140	14		3140	43.96	2.79	39.06	–	–		Difficult part for transportation. (Use ribbed for steel, cold bending required)
35		Rod ø 12 ℓ = 1890	5		1890	9.45	1.68	8.40	–	–		
36		Rod ø 12 ℓ = 2440	16		2440	39.04	2.17	34.72	–	–		Difficult part for transportation.
37		Rod ø 12 ℓ = 1790	8		1790	14.32	1.59	12.72	–	–		
38		Rod ø 25 ℓ = 2800	12		2800	33.60	10.78	129.36	–	–		Difficult part for transportation.
39		Rod ø 8 ℓ = 2060	8	R = 15 (outer dimensions)	2060	16.64	0.81	6.48	–	–		
TOTAL (1 – 39)				For cable ø 36 mm = 1068.49 kg; For cable ø 40 mm = 1081.89 kg					6.73 m²			

ONLY WHEN REQUIRED — Reinforcement for block with foot

Part no.	Section (mm)	Quantity	Working Drawing	Length Single/pc mm	Length total m	Weight kg/pc	Weight total kg	Surface m²/pc	Surface total m²	Steel supplied by	Remarks
40	Rod ø 12 ℓ = ...	....	ℓ' = ... Extra length for one hook = 120 Weight = 0.888 kg/m'	....	....	....	....	–	–		(Use ribbed for steel, cold bending required)
41	Rod ø 16 ℓ = ...	....	ℓ' = ... Extra length for one hook = 160 Weight = 1.58 kg/m'	....	....	....	....	–	–		
42	Rod ø 16 ℓ = ...	....	R = 50 (C + 800) Extra length for one hook = 160 Weight = 1.58 kg/m'	....	....	....	....	–	–		C: Refer to structural drawing 93/2.
43	Rod ø 12 ℓ = ...	....	ℓ' = ... Extra length for one hook = 120 Weight = 0.888 kg/m'	....	....	....	....	–	–		
44	Rod ø 16 ℓ = ...	....	ℓ' = ... Extra length for one hook = 160 Weight = 1.58 kg/m'	....	....	....	....	–	–		
TOTAL (1 – 44) =			.... kg					6.73 m²			

Remark:

If ℓ > 1.85m rod to be considered as difficult part for transportation.

Walkway

STEELPART LIST

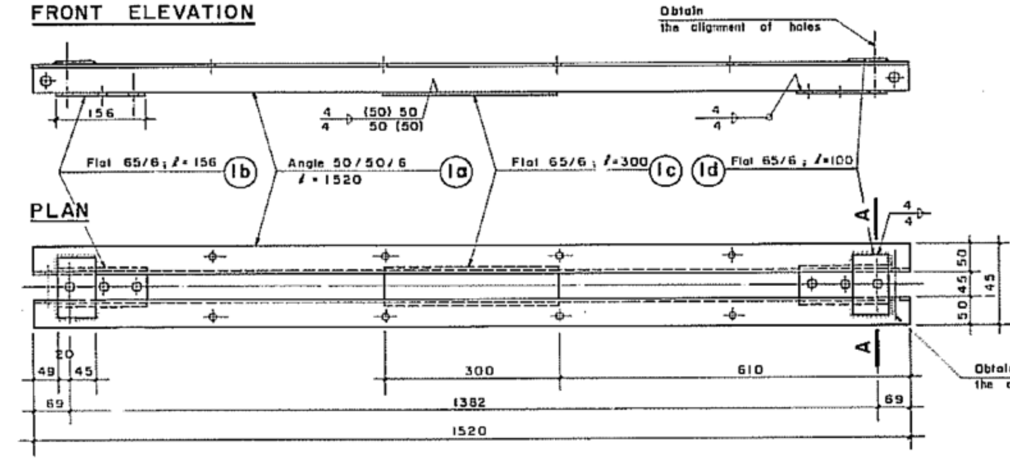
Part no.		Section (mm)	Quantity	Working Drawing (Dimension in mm)	Length Single/pc mm	Length total m	Weight kg/pc	Weight total kg	Surface to be painted m²/pc	Surface to be painted total m²	Steel supplied by	Remarks
I	a	Angle 50/50/6 l = 1520	2	4 holes ø 14 ; 2 holes ø 21	1520	3.040	6.778	13.556	0.304	0.608		
	b	Flat 65/6 l = 156	2	3 holes ø 17 thickness = 6	156	0.312	0.446	0.892	0.020	0.040		
	c	Flat 65/6 l = 300	1	thickness = 6	300	0.30	0.918	0.918	0.040	0.040		
	d	Flat 65/6 l = 100	2	1 hole ø 17 thickness = 6	100	0.20	0.295	0.590	0.011	0.022		Weight of one welded unit = 15.956kg Part nos. I (a-d) to be welded together as shown in welding detail.
2		Flat 40/6 l = 1720	2	3 holes ø 17 ; thickness = 6	1720	3.440	3.236	6.472	0.156	0.316		
3		Rod ø 16 l = 437	2	Thread M 16; R = 21 (inside); Rod to be bent as shown.	437	0.874	0.637	1.274	0.010	0.020		
4		Flat 40/6 l = 88	2	R = 7 (inside); 1 hole ø 17 thickness = 6	88	0.176	0.157	0.314	0.008	0.016		
5		Hexagonal bolt M 16x50 IS 1363	3.15	Thread M 16	–	–	0.106	0.334	Galvanized			5 % extra pieces. Ref. IS 1363-1967.
6		Hexagonal nut M 16 IS 1363	12.6	Thread M 16	–	–	0.032	0.403	Galvanized			5 % extra pieces. Ref. IS 1363-1967.
7		Hexagonal bolt M 12x70 IS 1363	8.4	Thread M 12	–	–	0.073	0.613	Galvanized			5% extra pieces. Ref. IS 1363-1967.
8		Hexagonal nut M 12 IS 1363	16.8	Thread M 12	–	–	0.018	0.302	Galvanized			5% extra pieces. Ref. IS 1363-1967.
9		Plain Washer ø 13	8.4	ø 24; ø 13; 3	–	–	0.008	0.067	Galvanized			5 % extra pieces
10		Wire Nail ø 5 l = 100	40		–	–	0.015	0.600	Galvanized			Used for fixing the longitudinal planks.
11		Binding Wire ø 1.6				9.00		0.142	Galvanized			Used for fixing the wire-mesh netting.
				TOTAL (I-II) =				26.477 kg	1.062 m²			

Longitudinal wooden planks length = 2.39 m
Volume per m span = 0.0759 m³ (Including 10% more for sawing)

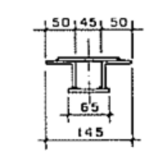
WELDING DETAIL OF PART I

1 : 5

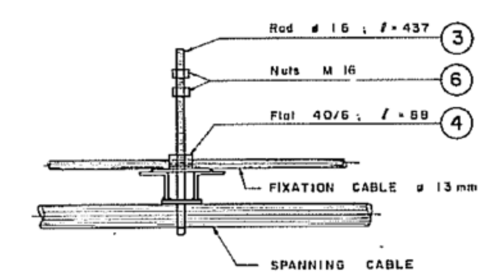
FRONT ELEVATION



SECTION A-A



SECTION C-C



Serial number	Item	Supplied by S.B.D. (kg)	Supplied by Workshop (kg)	Total weight (kg)
1	Structural steel, standard parts:			24.016
	Cost estimate para no.	01(RA)	01(RA)	02.1(A)
2	Screws, bolts, nuts, washers			1.719
	Standard parts: Cost estimate para no.	01(RA)	01(RA)	–
3	Reinforcement steel:			0.742[1)]
	Cost estimate para no.	01(RA)	01(RA)	02.2(A)
	Total 1+2+3			26.477
	Cost estimate para no.	01.11(A)	01.12(A)	–

A: Abstract of estimated cost , RA: Rate analysis
1) Nails and binding wire.

Anchorage

STEELPART LIST

Part no.		Section (mm)	Quantity	Working Drawing (Dimension in mm)	Length Single/pc mm	Length total m	Weight kg/pc	Weight total kg	Surface to be painted m²/pc	Surface to be painted total m²	Steel supplied by	Remarks
1	a	Flat 80/8 l=500	4	6 holes ø 14 thickness = 8	500	2.00	2.45	9.80	0.08	0.32		
	b	Flat 160/10 l=1100	8	4 holes ø 17, 3 holes ø 14, 1 hole ø 70 +0.074/−000, thickness=10	1100	8.80	13.34	106.72	0.36	2.88		Gas cutting prohibited for part no. 1b
	c	IS Square bar 80 l=150	4	Drill ø 10; Drill ø 46; Turned; R=2.5; 1 hole ø 46, 2 holes ø 10	150	0.60	4.90	19.60	0.04	0.16		
	d	Rod ø 10 l=110	8		110	0.88	0.07	0.56	–	–		Weight of one welded unit=46.46kg
	e	Rod ø 45 l=1000	4	thread M 45; THREAD DATA Major Dia.=45.000 Minor Dia.=39.479 Pitch = 4.5	1000	4.00	11.52	46.08	0.05	0.20		Part nos. 1 (a–f) to be welded together as shown in welding detail.
	f	Hexagonal nut M 45	4	Thread M45; THREAD DATA Major Dia=45.000 Minor Dia=40.129 Pitch = 4.5	–	–	0.77	3.08	–	–		
2		Flat 40/6 l=460	4	4 holes ø 14 thickness = 6	460	1.84	0.84	3.36	–	–		
3	a	Channel ISMC 200-500	4	4 holes ø 17; 1 hole ø 90 +0.087/−000; holes for socket cable end	500	2.00	10.71	42.84	0.25	1.00		
	b	Plate 183/60/10	8	Slope to suit channel flange. (see welding detail) Grind as necessary	–	–	0.79	6.32	0.03	0.24		
	c	Plate 480/180/8	4	1 hole ø 90 +0.087/−000; Bore after welding to part no. 3a; thickness = 8	–	–	5.03	20.12	0.08	0.32		Weight of one welded unit=45.68 kg
	d	Plate 200/66/10	8	thickness = 10	–	–	1.04	8.32	0.03	0.24		
	e	Plate 220/100/12	8	1 hole ø 47 thickness = 12	–	–	1.72	13.76	0.03	0.24		Part nos. 3 (a–e) to be welded together as shown in welding detail.
4		Pin ø 90 l=180	2	R=4; 2 holes ø 10	180	0.36	8.88	17.76	Apply grease only			
5		Split pin ø 8 l=150	4		–	–	0.06	0.24	Bright	steel		
6	a	Channel ISMC 125-1000	8	4 holes ø 17; 6 holes ø 14	1000	8.00	12.61	100.88	–	–		Weight of one welded unit=13.25 kg
	b	Plate 120/120/6	8	4 holes ø 17 thickness = 6; Bore after welding to part no. 6a	–	–	0.64	5.12	–	–		Part nos. 6 (a–b) to be welded together as shown in welding detail.
7		Flat 40/6 l=1160	4	4 holes ø 14 thickness = 6	1160	4.64	2.17	8.68	–	–		
8		Angle 50/50/6 l=630	4	6 holes ø 14	630	2.52	2.79	11.16	–	–		
9		Flat 100/10 l=1700	16	8 holes ø 17; thickness = 10	1700	27.20	13.20	211.20	–	–		
10		Angle 50/50/6 l=1500	2	6 holes ø 14 thickness = 6	1500	3.00	6.71	13.42	–	–		
11		Angle 50/50/6 l=1490	2	Cutoff the flange; 7 holes ø 14	1490	2.98	6.28	12.56	–	–		
12		Angle 50/50/6 l=1400	2	Cutoff the flange; 7 holes ø 14	1400	2.80	5.88	11.76	–	–		
13		Hexagonal nut M 45	13	This part is identical to part no. 1f	–	–	0.77	10.01	–	–		1 pc. extra.
14		Hexagonal bolt M 12 x 40 IS 1363	75	Thread M12	–	–	0.049	3.68	Galvanized			3 pcs. extra. Ref: IS 1363-1967
15		Hexagonal bolt M 16 x 60 IS 1363	100	Thread M16	–	–	0.12	12.00	Galvanized			4 pcs. extra. Ref: IS 1363-1967
16		Hexagonal nut M12 IS 1363	75	Thread M12	–	–	0.018	1.35	Galvanized			3 pcs. extra. Ref: IS 1363-1967
17		Hexagonal nut M16 IS 1363	100	Thread M16	–	–	0.032	3.20	Galvanized			4 pcs. extra. Ref: IS 1363-1967
18		Plain washer ø 17 thickness = 4	100		–	–	0.015	1.50	Galvanized			4 pcs extra.
19		Rod ø 25 l=2650	2	Rod to be bent to form the hook; R=15 (inside); R=50; Surface to be painted.	2650	5.30	10.20	20.40	0.04 (Partly	0.08 painted)		Used for fixing Tirfor Machine during erection.
TOTAL (1 – 19) =								725.48 kg	5.68 m²			

ONLY WHEN REQUIRED

Part no.	Section (mm)	Quantity	Working Drawing	Length Single/pc mm	Length total m	Weight kg/pc	Weight total kg	Surface m²/pc	Surface total m²	Steel supplied by	Remarks
20	Rod ø 25 l=	......	Extra length for hook = 250 Weight = 3.85kg/m'	......	......	......	......	–	–		Ribbed tor steel. Cold bending required.
21	Plate 240/220/16	......	Plate bolted to part 3a when cable end is socketed; 1 hole ø 43, 4 holes ø 17; When this plate is used for socketed cable end, part no. 4 and 5 are not necessary.	–	–	6.34		0.12	......		
22	Hexagonal bolt M 16 x 60 IS 1363		Identical to part no. 15	–	–	0.12	......	Galvanized			Ref: IS 1363-1967
23	Plain washer ø17 thickness = 4		Identical to part no. 18	–	–	0.015	......	Galvanized			
24	Hexagonal nut M 16 IS 1363		Identical to part no. 17	–	–	0.032	......	Galvanized			Ref: IS 1363-1967
25	Taper washer ø 18 IS 5372	......	Taper washer nominal hole size ø 18 as per ISI	–	–	0.035	......	Galvanized			Ref: IS 5372-1975
26	Flat 100/10 l = 1545	......	12 holes ø 17, thickness = 10	1545	......	11.91	......	–	–		Use for extending the length of part no. 9. (Deadman anchorage)
27	Mortar container Sheet 1 = 0.5	......	r = 12.5; Total about 250 holes ø 4	1400	......	0.21	......	–	–		Two units per anchor bar (20)
TOTAL (20–27) =							...... kg	...... m²			

Part no.	Section (mm)	Quantity	Working Drawing	Length Single/pc mm	Length total m	Weight kg/pc	Weight total kg	Surface m²/pc	Surface total m²	Steel supplied by	Remarks
28	Open thimble	2	Thimble to ISI standard for cable ø ...... mm	–	–	......*	......	Galvanized			Ref: IS 2315 – 1978
29	Bulldog grip	......*	M.S. forged bulldog grip to ISI standard for cable ø ...... mm	–	–	......*	......	Galvanized			Ref: IS 2361 – 1970
GRAND TOTAL =							...... kg	...... m²			

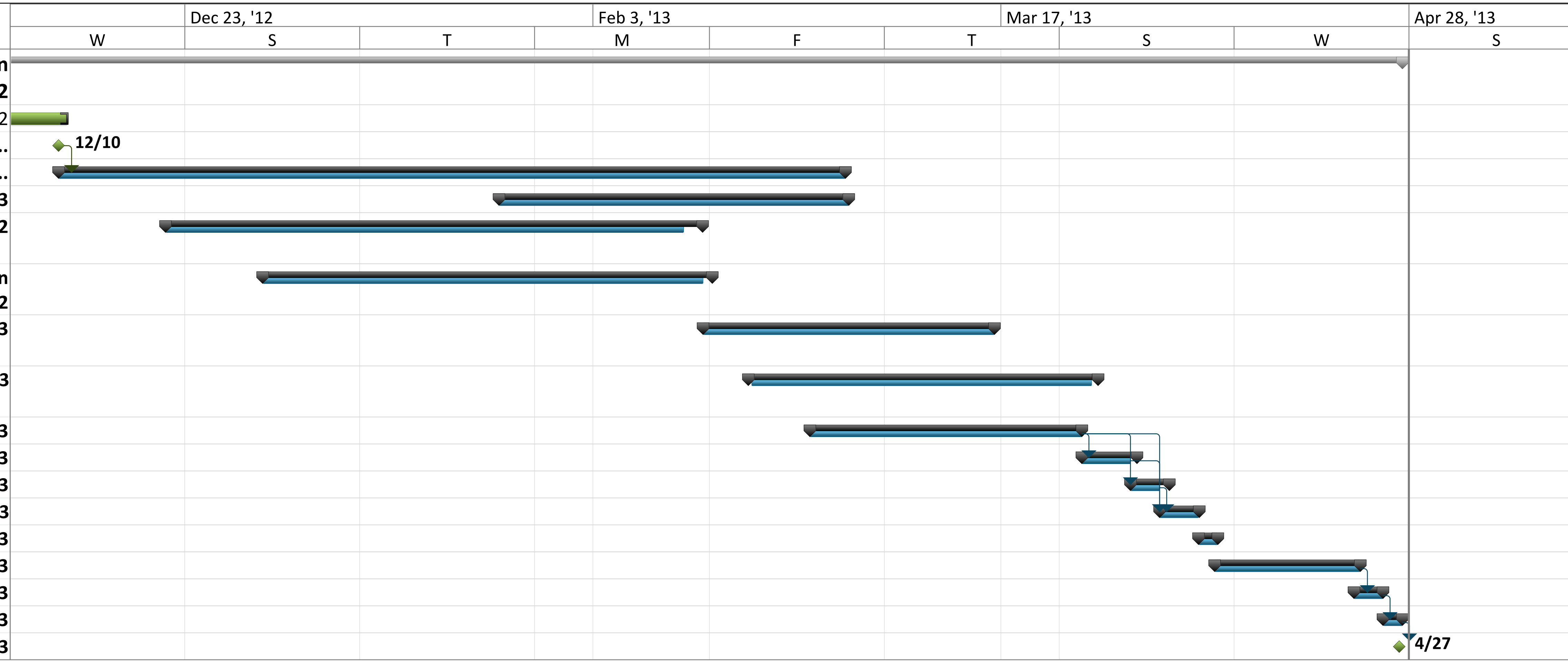
*

Cable ø mm	Bulldog grips for one cable	Weight (kg/pc) Thimble	Weight (kg/pc) B. grip
36	7	2.75	1.85
40	8	3.20	2.40

APPENDIX L: CONSTRUCTION SCHEDULE

Chichica Footbridge Construction Schedule

ID	Task Name	Duration	Start
0	**Construction Schedule**	**275.25 days?**	**Mon 6/11/12**
1	Project Mobilization	157 days	Mon 6/11/12
2	**Project Start**	**0 days**	**Mon 12/10/...**
3	**Bridge Site Preparation**	**70 days**	**Mon 12/10/...**
10	**Steel Assemblies Fabrication**	**31 days**	**Thu 1/24/13**
19	**Excavation & Foundation Construction North**	**47.13 days**	**Fri 12/21/12**
27	**Excavation & Foundation Construction South**	**40.13 days**	**Mon 12/31/12**
35	**Excavation & Anchorage Construction North**	**26 days**	**Thu 2/14/13**
45	**Excavation & Anchorage Construction South**	**31 days**	**Tue 2/19/13**
55	**Cable Transportation**	**24 days**	**Mon 2/25/13**
58	**Tower Erection North**	**5.75 days**	**Mon 3/25/13**
66	**Tower Erection South**	**3 days**	**Sat 3/30/13**
74	**Hoisting Main Cables**	**4.25 days**	**Tue 4/2/13**
82	**Hoist Spanning Cables**	**1 day?**	**Sat 4/6/13**
87	**Suspenders and Walkway**	**13 days**	**Mon 4/8/13**
101	**Adjacent Site Works**	**3 days**	**Mon 4/22/13**
104	**Site Completion**	**2 days**	**Thu 4/25/13**
109	**Project End**	**0 days**	**Sat 4/27/13**



Project: Construction Schedule
Date: Mon 11/14/11

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

CHICHICA FOOTBRIDGE
CONSTRUCTION WORK ASSIGNMENTS

No.	Activity
1.0	Project Mobilization
2.0	Bridge Site Preparation
3.0	Steel Assemblies Fabrication
4.0	Excavation & Foundation Construction North
5.0	Excavation & Foundation Construction South
6.0	Excavation & Anchorage Construction North
7.0	Excavation & Anchorage Construction South
8.0	Suspension Cable Transportation
9.0	Tower Erection North
10.0	Tower Erection South
11.0	Hoist Main Cables
12.0	Hoist Spanning Cables
13.0	Suspenders and Walkway
14.0	Adjacent Site Works
15.0	Site Completion

CHICHICA FOOTBRIDGE
CONSTRUCTION WORK BREAKDOWN STRUCTURE

ACTIVITIES

1.0 Project Mobilization

2.0 Bridge Site Preparation

- 2.1 Transportation of storage facilities materials
- 2.2 Construct storage facilities
- 2.3 Site clearing
- 2.4 Transportation of footbridge materials
- 2.5 Transportation of equipment to site
- 2.6 Site layout

3.0 Steel Assemblies Fabrication

- 3.1 Foundation
- 3.2 Transportation of foundation steel assemblies
- 3.3 Anchorage
- 3.4 Transportation of anchorage steel assemblies
- 3.5 Tower
- 3.6 Transportation of tower steel assemblies
- 3.7 Walkway & Suspenders
- 3.8 Transportation of walkway & suspenders steel assemblies

4.0 Excavation & Foundation Construction North

- 4.1 Excavation
- 4.2 Place masonry block
- 4.3 Build forms surrounding masonry block
- 4.4 Concrete fill (1st portion)
- 4.5 Concrete fill (2nd, 3rd, and 4th)
- 4.6 Foundation steel assembly installation and finish concrete work
- 4.7 Backfill and grading around foundation

5.0 Excavation & Foundation Construction South

- 5.1 Excavation
- 5.2 Place masonry block
- 5.3 Build forms surrounding masonry block
- 5.4 Concrete fill (1st portion)
- 5.5 Concrete fill (2nd, 3rd, and 4th)
- 5.6 Foundation steel assembly installation and finish concrete work
- 5.7 Backfill and grading around foundation

6.0 Excavation & Anchorage Construction North

- 6.1 Excavation
- 6.2 Formwork
- 6.3 Concrete fill (1st portion)
- 6.4 Concrete fill (2nd portion)
- 6.5 Anchorage steel assembly installation
- 6.6 Formwork
- 6.7 Concrete fill (3rd portion)
- 6.8 Concrete finish work
- 6.9 Backfill

7.0 Excavation & Anchorage Construction South

- 7.1 Excavation
- 7.2 Formwork
- 7.3 Concrete fill (1st portion)
- 7.4 Concrete fill (2nd portion)
- 7.5 Anchorage steel assembly installation
- 7.6 Formwork
- 7.7 Concrete fill (3rd portion)
- 7.8 Concrete finish work

8.0 Suspension Cable Transportation

- 8.1 Norfolk, VA U.S.A. to Panama City, Panama
- 8.2 Panama City to Tole
- 8.3 Tole to bridge site

9.0 Tower Erection North

- 9.1 Assemble Base, Intermediate, Top, and Saddle element
- 9.2 Re-apply anti-corrosion paint
- 9.3 Fix 13mm cable to top of tower and opposite foundations
- 9.4 Apply Tower Stay Chains
- 9.5 Apply Protective Wood between Stay Cables and Tower Legs
- 9.6 Tower Erection
- 9.7 Install Temporary braces at tower base

10.0 Tower Erection South

- 10.1 Assemble Base, Intermediate, Top, and Saddle element
- 10.2 Re-apply anti-corrosion paint
- 10.3 Fix 13mm cable to top of tower and opposite foundations
- 10.4 Apply Tower Stay Chains
- 10.5 Apply Protective Wood between Stay Cables and Tower Legs
- 10.6 Tower Erection
- 10.7 Install Temporary braces at tower base

11.0 Hoist Main Cables

- 11.1 Execute Temporay Cable Hoisting Aid
- 11.2 Mark all Cable Hoisting Positions
- 11.3 Pull Main Cables Along Spanning Cables
- 11.4 Hoist Cable onto North Tower from each Side
- 11.5 Hoist Cable onto South Tower from each Side
- 11.6 Fix Hoisting Sag
- 11.7 Check Hoisting Sag Elevation

12.0 Hoist Spanning Cables

- 12.1 Fix Cable on one Side to Foundation Anchorage
- 12.2 Tension Spanning Cable
- 12.3 Fix Cable at Deadload Sag
- 12.4 Check Hoisting Sag Elevation

13.0 Suspenders and Walkway

13.1 Construct Fitter Platform

13.2 Hang Platform under Main Cable

13.3 Organize Suspender Material and Walkway Cross-Beams

13.4 Fabricate Nailing Strips

13.5 Set up Pulley System for Platforms

13.6 Fit the Central Suspender

13.7 Hang Suspenders and Install Walkway Platform

13.8 Install Fixation and Handrail Cables

13.9 Disassemble Fitter Platform and Pulley System

13.10 Pre-cut Decking Material to Size

13.11 Install Deck Material

13.12 Install Wire Mesh

13.13 Test Loading and Check Main Cable Elevation

14.0 Adjacent Site Works

14.1 Site Clearing

14.2 Erosion Protection

15.0 Site Completion

15.1 Removal of Equipment

15.2 Removal of Waste

15.3 Removal of Temporary Facilities

15.4 Re-check Bridge Characteristics and Cable Elevations

APPENDIX M: SELECTED BRIDGES TO PROSPERITY MANUAL PAGES

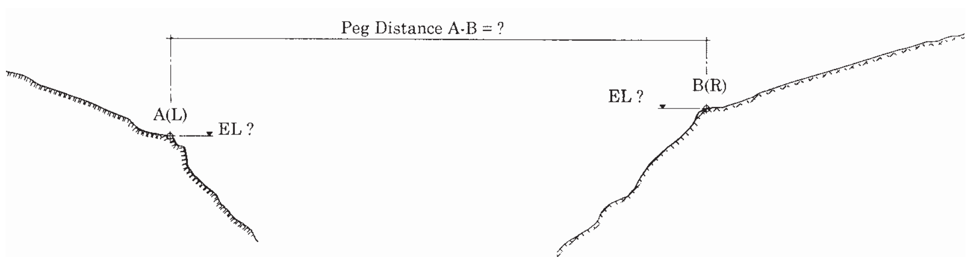
6. CONSTRUCTION

6.1 BRIDGE LAYOUT

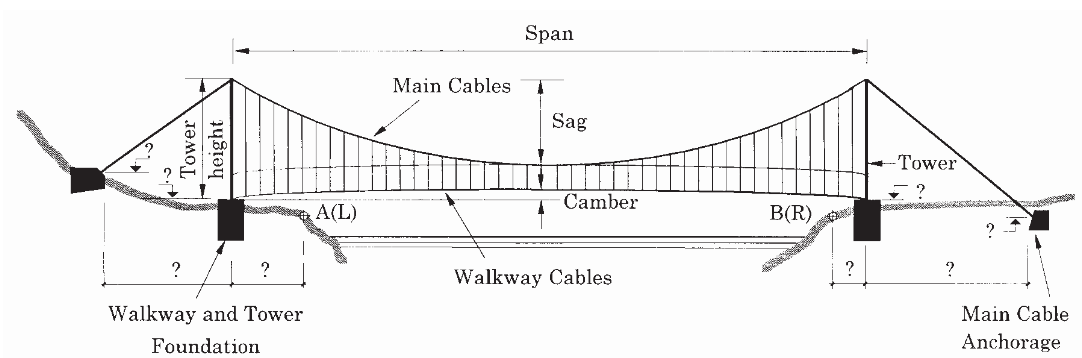
The Bridge Layout is to fix the bridge position and foundations at the site as per the design.

Procedure for General Bridge Layout (refer to General Arrangement 'GA' Drawing):

- Find the existing pegs and Bench Marks.
- Measure the horizontal distance between the axis pegs A (L) and B(R), and compare with the measurement given in the General Arrangement.
- Check the elevations of the axis pegs A (L) and B(R), and compare with the elevations given in the GA.

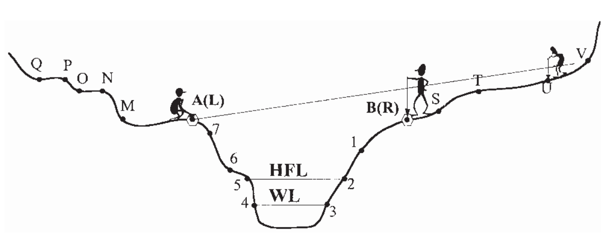


- If the horizontal distance between the axis pegs A (L) and B(R) and their elevations are not similar to the measurements given in the GA, readjust the design according to the actual measurements.
- If the horizontal distance between the axis pegs A (L) and B(R) and their elevations are identical to the measurements given in the GA, fix the position of all the foundation blocks as shown in the following sketch and procedure.

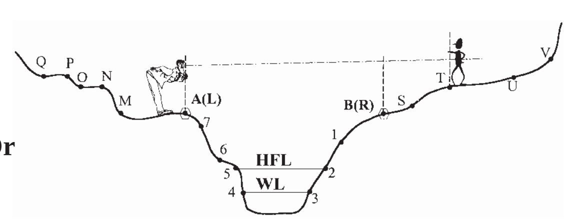


Procedure for Detailed Foundation Layout:

- Align the centerline of the bridge by joining the permanent points with mason threads or by ranging between the axis pegs 'A' and 'B' as shown in the following sketches.

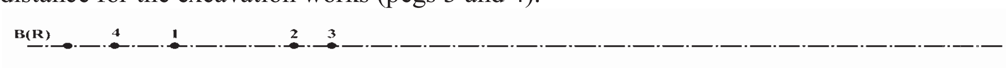


Or

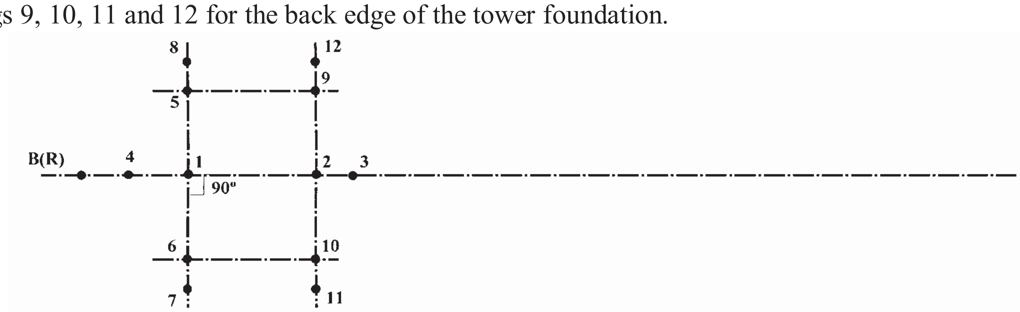


- Mark the front of the tower foundation on the bridge centerline (peg 1) with reference to the axis peg. The distance between the front of the tower foundation and the axis peg is given in the GA.

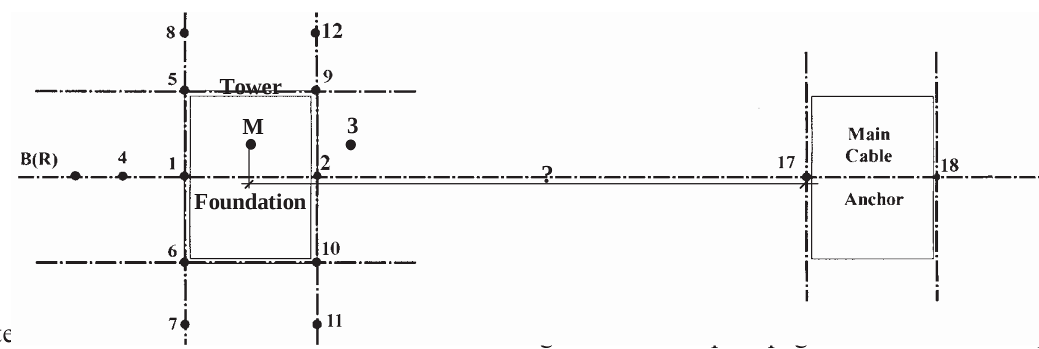
- Check the location of the front of the tower to ensure that it is at a sufficient distance (minimum 3m for soil slope and 1.5m for rock slope) from the bank edge. (Refer to Chapter 3.3.3).
- Measure the length of the foundation from peg 1 and fix peg 2. Set up two additional centerline pegs at a safe distance for the excavation works (pegs 3 and 4).



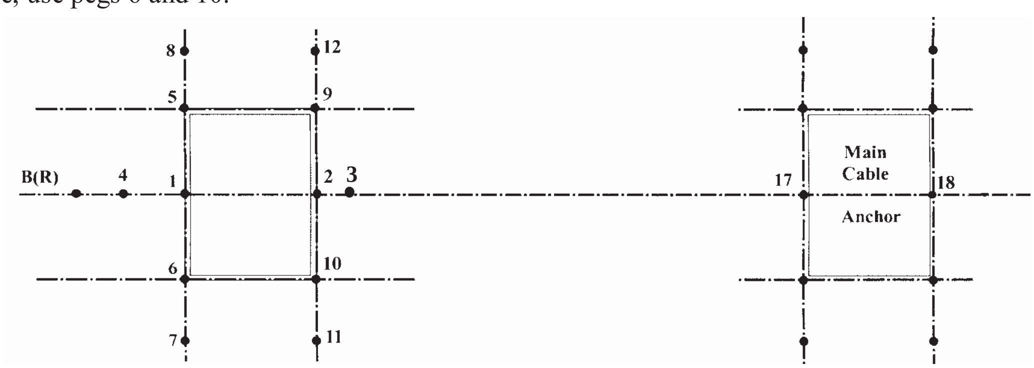
- Draw an offset line (right angle) through pegs 1 and 2 by the 3-4-5 method (refer to Chapter 2.5.4). Starting from peg 1, set out pegs 5, 6, 7 and 8 for the reference line of the front edge, and from peg 2 for pegs 9, 10, 11 and 12 for the back edge of the tower foundation.



- Determine the center point of the tower foundation and measure the distance between the tower axis and the front of the main cable anchor and fix peg 17. Draw an offset line through peg 17 as a reference line of the front edge. Set up one additional centerline peg at a safe distance behind and proceed as above.



- Dete … pstream edge, use pegs 6 and 10.



- Fix the elevation line (datum level), and indicate the depth of the excavation work for the tower foundation and the main cable anchor as per the elevations shown in the GA and Anchorage Drawings.

6.2 FOUNDATION EXCAVATION

In Soil:

The foundations should be excavated with slopes to provide stability in the cut slope. The cut slope in soil should generally not exceed 3:1 (V:H). The foundations should be excavated stagewise. Trenches should be excavated vertically with sheeting, or must be banked with slopes which afford the necessary stability.

All safety requirements for the protection of personnel during excavation must be met.

Slope Pitch

- in well consolidated stable ground, maximum slope pitch 3:1 (3m vertical, 1m horizontal)
- in moderately consolidated but stable soil, maximum slope pitch 2:1 (2m vertical, 1m horizontal)
- in non-cohesive ground, maximum slope pitch 1:1 (1m vertical, 1m horizontal)

If slope stability is impaired by unfavorable strata morphology, artesian water, intermediate friction layers, vibration, etc. the slope pitch must be reduced.

The most important point to be borne in mind during excavation is the fact that almost every bridge foundation bed is inclined. It is not allowed to excavate horizontally and form the incline with fill material!

To ensure that the foundation bed is clean and undisturbed, the bottom 10cm should be excavated only shortly before the concrete is poured.

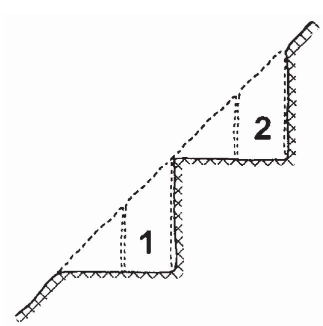
During all excavation stages, the excavation depth should be accurately maintained. For this, establish an elevation line (datum level) and measure the foundation depths with fixed sticks.

All the excavated soil should be safely disposed of without damaging the existing vegetation down hill, thus not affecting the environment.

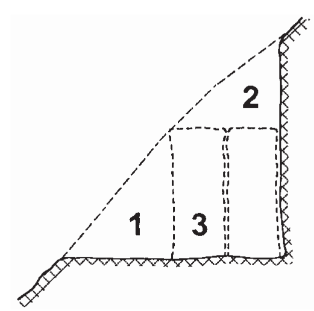
In Rock:

Rock excavation is necessary to prepare the platform for a drum anchorage or for a rock block anchorage. The rock should be excavated manually without blasting.

Excavation in rock is done by first drilling holes to weaken the rock, and then using crowbars to break it up and dig out the pieces. The cutting can be carried out by forming steps, as shown in the following sketches.



1st Stage

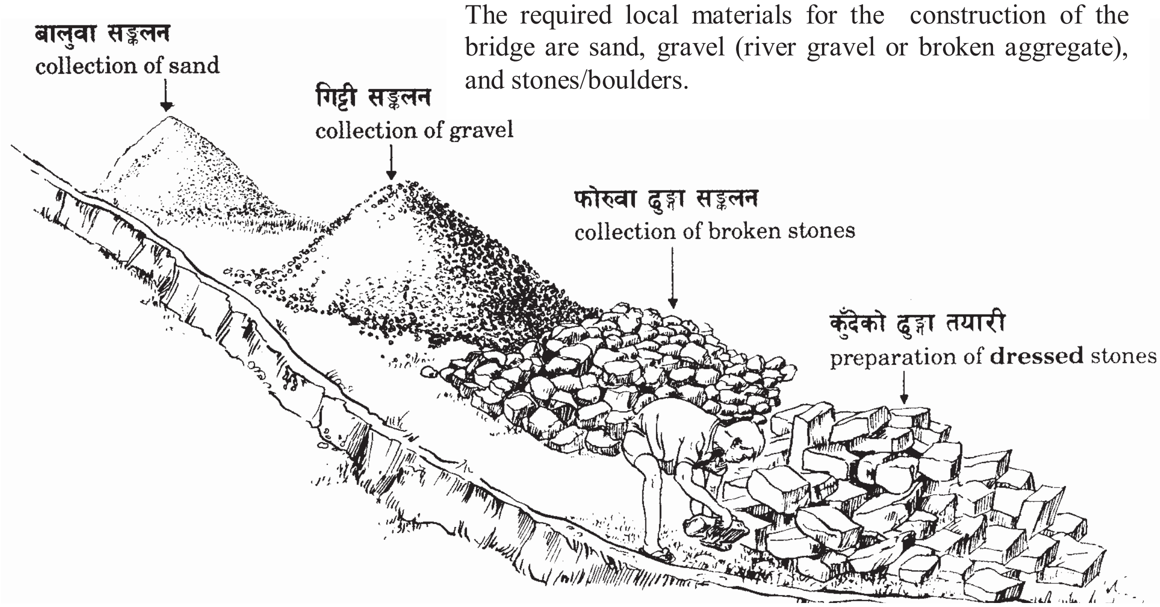


2nd Stage

Further details about drum anchorage foundation in rock is given in Chapter 6.6.4.

6.3 LOCAL MATERIAL COLLECTION

The required local materials for the construction of the bridge are sand, gravel (river gravel or broken aggregate), and stones/boulders.



6.3.1 STONES/BOULDERS

The best stone collection is from a rock quarry. The rock should be unweathered, hard and dense with a metallic sound.

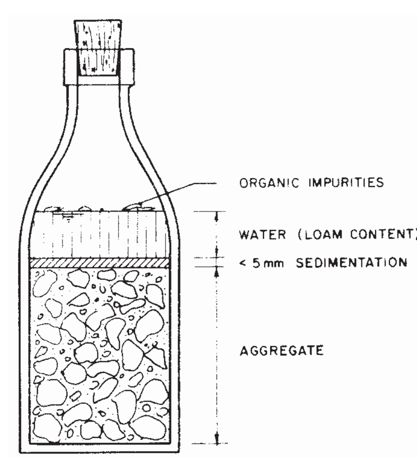
In unavoidable cases, boulders from river deposits can also be collected. However, this can be used only for filling purposes (broken stone filling). In any case, stones from a rock quarry are necessary for the masonry works.

The quality requirements for stones/boulders are further detailed in Chapter 6.5.1.

6.3.2 SAND

Sand can be collected from river deposits or from a quarry. The quality of the sand should be assessed before collection. Check the sand visually for impurities such as mica, clay, loam, mud organic materials, etc. If such impurities are unavoidable, it is recommended that the sand be washed before use. Sand containing significant quantities of mica should be rejected. The grain size of the collected sand should not be too fine.

Fill a bottle with sand and water and shake vigorously, and leave to settle. If the sand is clean, the sedimentation will be less than 5mm after two hours. And the water above will only be slightly cloudy.



The quality requirements for sand are further detailed in Chapter 6.6.1.

6.3.3 GRAVEL

Gravel can be collected from river deposits or by breaking boulders into the necessary size. The required sizes and their proportion should be

5 to 20mm - 40%
20 to 40mm - 60%

Gravel should be of hard rock origin. Gravel of unsuitable rock such as mica, marl and sandstone should be rejected. Likewise, flat and flaky particles should also be rejected. The collected gravel should be free from organic contaminants like clay, loam, mud or stone dust, etc.

The quality requirements for gravel are further detailed in Chapter 6.6.1.

6.4 TRANSPORTATION AND STORAGE OF THE MATERIALS

Materials other than local materials have to be transported from the roadhead to the site by porter or other means. These materials are mainly Cement, Steel Parts and Wire Ropes.

6.4.1 CEMENT TRANSPORTATION AND STORING

Utmost care should be taken during transportation and storage of the cement. The prime importance is the proper packing of the cement before transportation to make it watertight and airtight. For this, cement bags as received from the market or factory should be double packed by additional packing in Nylon Bags with a plastic layer inside. Re-opening the bags (especially when transporting by mules) is not permitted before use at the site.

The following rules must be observed while storing the cement:

- Cement must always be stored under a roof with adequate protection from rain. A raised plank floor is necessary to protect the cement from damp.
- Storage must be arranged in such a way that the oldest batch can be used first.

6.4.2 STEEL PARTS TRANSPORTATION AND STORING

There is a great chance of damage to steel parts during loading/unloading and transportation. The most common types of damage are:

- Deformation of tower parts, suspenders or steel decks due to mishandling during loading and unloading.

  All the steel parts should be loaded and unloaded carefully to avoid such damage. Do not allow steel parts to fall from a height.

  Similarly, the following rules must be observed while transporting and storing the steel parts to avoid any damage.

  - Galvanized **and** non-galvanized steel parts must always be stored under a roof with adequate protection from rain, and they should not be in contact with the ground.
  - Galvanized steel parts should not be transported or stored together with salt or acid.
  - Steel parts should be stacked and stored element/component-wise by avoiding mixing up the different elements. This way, any element or component can be easily located during the erection of the bridge.
  - All fixtures (nuts/bolts, washers, thimbles and bulldog grips) should be packed/marked and stored separately according to their sizes.
  - Steel parts, particularly suspenders and reinforcement bars, should not be bent during carriage and storage.

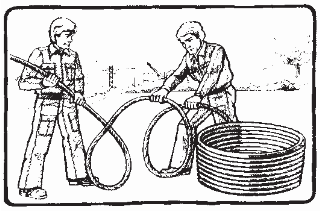
6.4.3 WIRE ROPE TRANSPORTATION AND STORING

It is vital to handle and transport the cables carefully in order to avoid causing any damage like kinks, splices and broken strands. Some examples of damage caused to cables due to mishandling and improper transportation are shown in the photographs below.

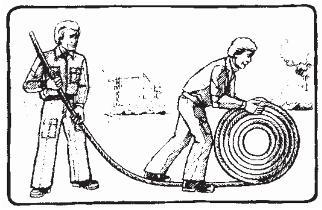
Also pulling or dragging the cable along the road during transportation is not permitted.

To avoid such harm, follow the handling and transportation methods as described below.

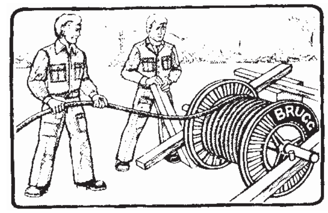
- **Method of Unreeling Light Cables with the Help of a Reel Support**



Wrong

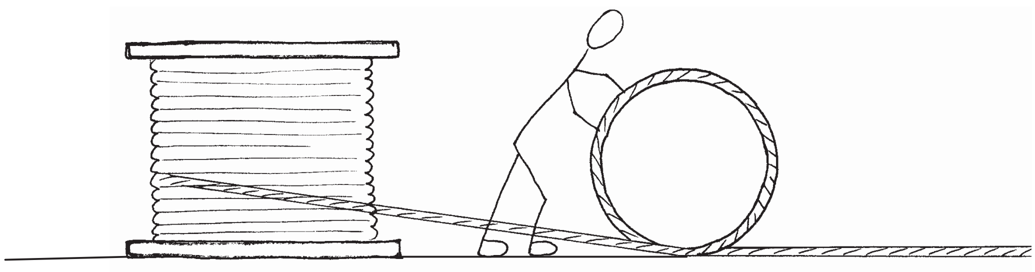


Correct

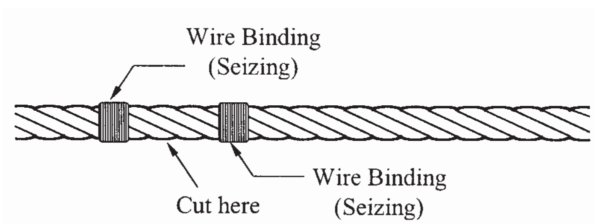


Correct

- **Method of Unreeling Cables by Unrolling Each Loop Taken from the Reel**.



Before cutting the cable, ends should be secured by a binding-wire (seizing) as shown in the following sketch to avoid loosening of the cable wires.



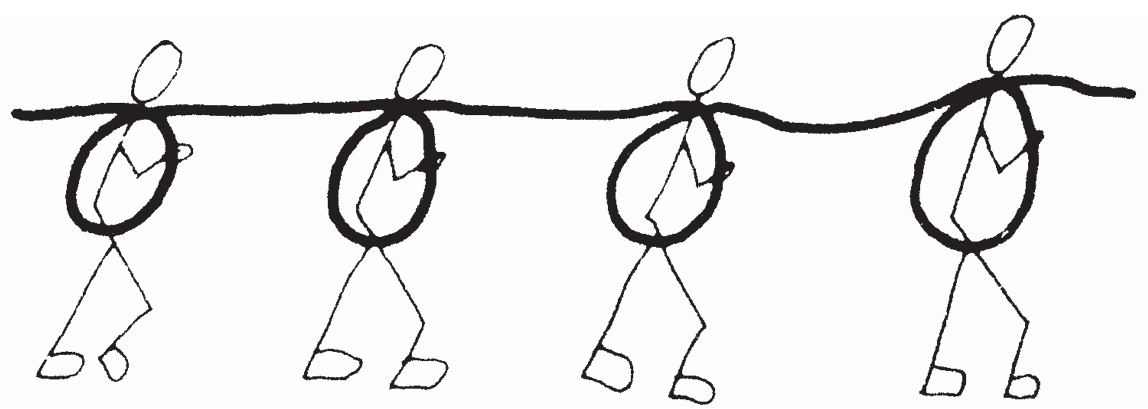
- **Method of Transportation by Porters**

There are mainly two methods of transporting cables as illustrated in the following photos.

Transporting a cable on the Shoulder (for short distances).

Bundled Cable Transportation (for longer distances)

Transporting cables as shown in the sketch below is wrong and should not be practiced.



Wrong method of cable transportation.

6.5.4 STONE MASONRY LAYING

There are many different kinds of stone masonries. For constructing anchor blocks and towers, only **coursed** (in layers of equal height) stone masonry is applied.

There are two types of stone masonries used for bridge construction:

- **Coursed Random Rubble Stone Masonry**

  The stones are hammer-dressed, except the inside face. The gaps between the beds and the joints shall not exceed 12 mm.
  All **Face Stones** tail into the wall twice their height.

  Bond Stones running right through the wall are inserted at 150 cm intervals at the least.

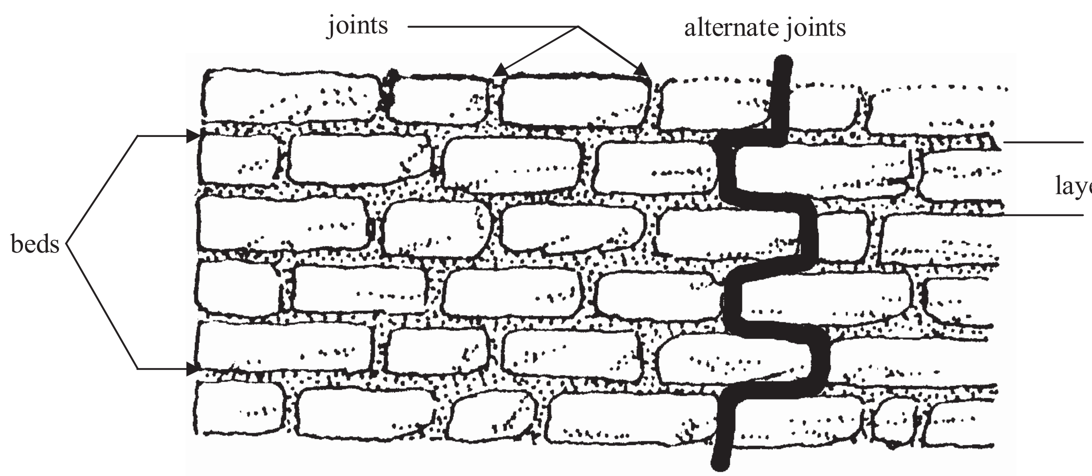
- **Coursed Block Stone Masonry**

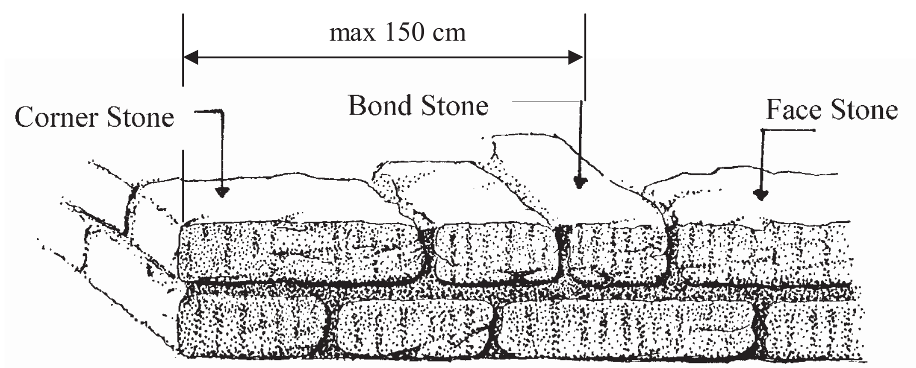
  The stones are chisel-dressed at all faces, except the inside face. The joints are dressed at right angles to the face. The gaps between the beds and the joints should not exceed 6 mm.

  All **Face Stones** tail into the wall twice their height.

  Bond Stones running right through the wall are inserted on each course at 150 cm intervals at the least.

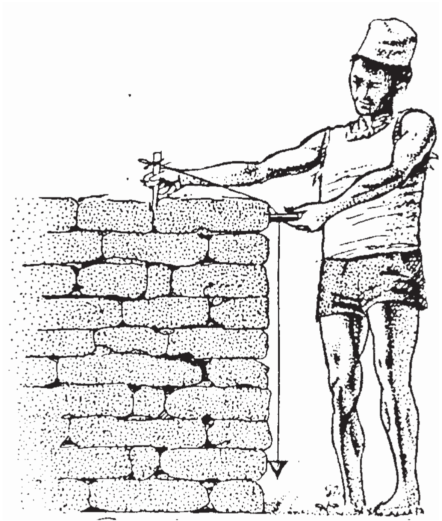
Course Stone Masonry must be made in **layers** of equal height. Individual layer heights may vary, but should never be less than 10 cm. **Alternate** joints should be made between the layers above and below as shown in the following sketch.



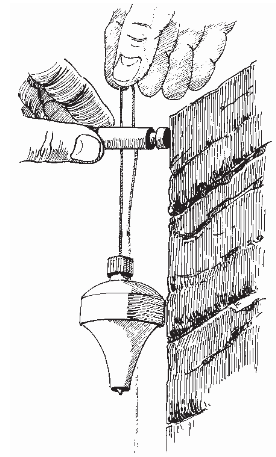


In a reasonably well-made stone masonry, the inner friction between the beds amounts to approximately 35°.

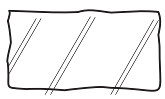
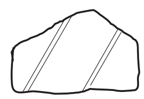
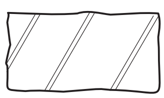
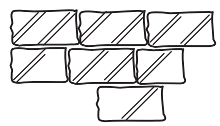
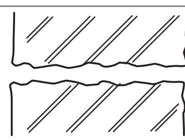
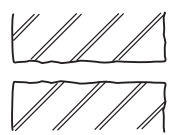
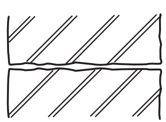
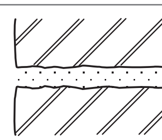
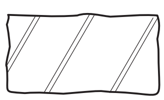
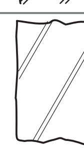
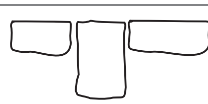
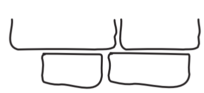
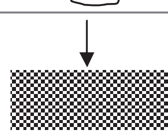
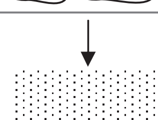
The verification of the corners and faces has to be done carefully with a plumb-bob.



Correct use of plumb-bob



The **Strength** of stone masonry structures depends mainly on the qualities described in the table below.

…bigger…		**The Strength of Stone Masonry is…**		**…smaller…**
…with rectangular stones.		**Form or Shape**		…with irregular stones.
…the less stones are used.		**Number**		…the more stones are used.
…the rougher the joints are.		**Roughness of joints**		…the smoother the joints are.
…the smaller the beds are.		**Bed**		…the bigger the beds are.
…the more compact the stones are.		**Height & Width**		…the slimmer the stones are.
…the better the bond across is.		**Bond Across (in plan view)**		…the worse the bond across is.
…the higher the strength of the mortar is.		**Strength of Mortar**		…the lower the strength of the mortar is.

6.6 CEMENT WORKS

6.6.1 COMPOSITION AND MIXTURES

Cement concrete is a mixture of the following four components:

- **Cement**

  Ordinary Portland Cement commonly used for general construction works.

- **Sand**

- **Gravel**

- **Water**

Cement is very sensitive to humidity and moisture; therefore it should never be stored for a long time. In the rainy season, cement bags have to be packed in additional sealed plastic bags plus additional nylon bags for protecting the cement against water and damage.

Sand should be clean, sharp, angular, hard and durable. Sand must be well washed and cleaned of mud or any organic material before use. A well-graded sand should be used for cement works. All or most of the sand should pass through a 3 mm sieve or mesh wire. However, it should not be too fine, only 15% of the sand at the most can be smaller than 150 microns, which is like dust.

Gravel should be clean, hard, angular and non-porous. Usually riverside gravel makes the best aggregate for preparing concrete. The corn size of gravel should be smaller than 40 mm (1½ inches) but bigger than 5 mm.

Water from rivers or lakes is usually suitable for making cement mixtures. Do not use water from ponds or swamps, it may contain a lot of organic materials.

The main characteristics of any cement work is given by the mix proportions of their components:

- **Cement Mortar = A mix of Cement and Sand**

- **Cement Concrete = a mix of Cement, Sand and Gravel**

Of course, **Water** is added in both cases, but the mix proportions of cement, sand and gravel give the main characteristics of any cemented work.

Mixing the above components thoroughly is of utmost importance. Hand mixing should be done on a clean watertight platform. Cement and sand should first be mixed dry, and then gravel added. Now the whole mixture should be turned over three times dry. Then mixing should take place for at least five minutes by slowly sprinkling water until the concrete is of a uniform color.

The table below depicts the most commonly used mix proportions and required quantities:

Quantities for various Types of Cement Works

Type of Cement Work	Mix. proportions Cement : Sand : Gravel	Dry required quantities for **one cubic meter** wet: Cement bags @ 50 kg	kg	Sand [m³]	Gravel [m³]	Stones or Boulders [m³]
Cement Mortars	**1 : 1 -**	**20.4**	**1020**	**0.71**	-	-
	1 : 2 -	**13.6**	**680**	**0.95**	-	-
	1 : 3 -	**10.2**	**510**	**1.05**	-	-
	1 : 4 -	**7.6**	**380**	**1.05**	-	-
	1 : 6 -	**5.0**	**250**	**1.05**	-	-
Cement Plaster (20 mm includes 12% waste)	**1 : 4 -**	**0.18**	**9**	**0.024**	-	-
	1 : 6 -	**0.12**	**6**	**0.024**	-	-
Cement Stone Masonries	**1 : 4** uncoursed stone masonry	**2.66**	**133**	**0.37**	-	**1.1**
	1 : 6 uncoursed stone masonry	**1.75**	**87.5**	**0.37**	-	**1.1**
	1 : 4 coursed stone masonry	**2.28**	**114**	**0.32**	-	**1.1**
	1 : 6 coursed stone masonry	**1.50**	**75**	**0.32**	-	**1.1**
Cement Concretes (plain or reinforced)	**1 : 4 : 8**	**3.4**	**170**	**0.47**	**0.94**	-
	1 : 3 : 6 (M10)	**4.4**	**220**	**0.47**	**0.89**	-
	1 : 2 : 4 (M15)	**6.4**	**320**	**0.45**	**0.85**	-
	1 : 1½ : 3 (M20)	**8**	**400**	**0.42**	**0.84**	-
"Plum" Concrete	**1 : 3 : 6** with 50% boulders	**2.64**	**132**	**0.28**	**0.54**	**0.50**

Source: Indian Practical Civil Engineers' Handbook, Section 20

The amount of **Water** should be about half the volume of cement. One 50-kg bag of cement has a volume of approximately 35 liters, which is equal to approximately two kerosene tins.

Concrete and **Mortar** should be placed in its final position within one hour. After placing, it should be well compacted with the help of rods in order to remove any air pockets. For concrete of high quality, good compaction is essential. This may mean extra work during placing, but on no account should more water be added for reducing the compacting work. Concreting should never be done if it is raining.

Curing means keeping completed cement works wet until the setting process is completed. If concrete works are not kept continuously wet during the setting process, cement mortar, cement stone masonry work and especially concrete do not develop their full strength. Curing should be done for at least 28 days.

For increasing the strength of concrete, ribbed Tor-Steel bars are added which makes Reinforced Cement Concrete or RCC.

6.7 BRIDGE ERECTION

As soon as the anchor blocks and tower foundations are completed, the bridge erection works can be started. Bridge erection and fitting works are somewhat difficult and dangerous, and require especially skilled laborers who will not suffer from giddiness. Because of this somewhat risky work, the necessary safety precautions should strictly be followed and the respective responsibilities should be clarified before starting the work.

6.7.1 ERECTION OF TOWERS

The towers must be temporarily fixed during erection, because they rest as a line load on the base plate which acts like a hinge. In order to avoid serious accidents during erection, the towers must be temporarily fixed at their base. For this purpose, temporary side struts have been provided at the tower and walkway foundation with an additional 8 angles for each tower (see position B-5 of Base Element Drawing No. 100N). The angles are supplied with holes at one end only, the exact position of the required hole at the other end must be marked at the site when erecting the base element.

First fix both the Base Elements at the bottom and put them in an exactly vertical position. Fix the temporary angles at the bottom of each side, then mark the required position of the hole at the other end of the angle. Also give a position number to each angle so that they won't get mixed up. Have one hole of ø 17mm drilled at the site or at the nearest workshop.

For tower erection, refer to the respective Assembly and Layout Drawings.

- Check Steel parts for labels and numbers put by the manufacturer.
  - Use steel-cones for easy fitting works and tighten the nuts and bolts fully only after the next diagonal bracing has been put in place.

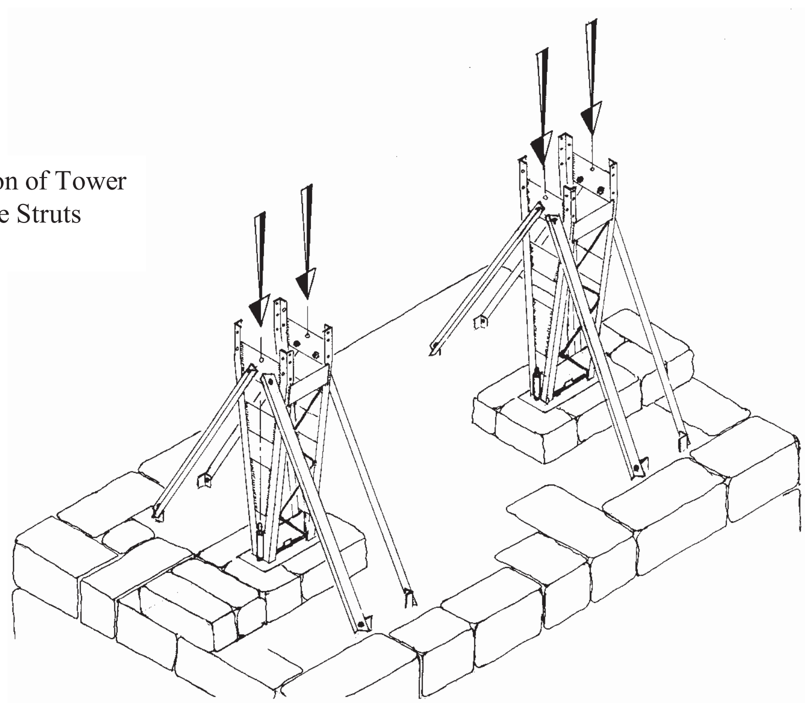
Each tower consists of the following parts :

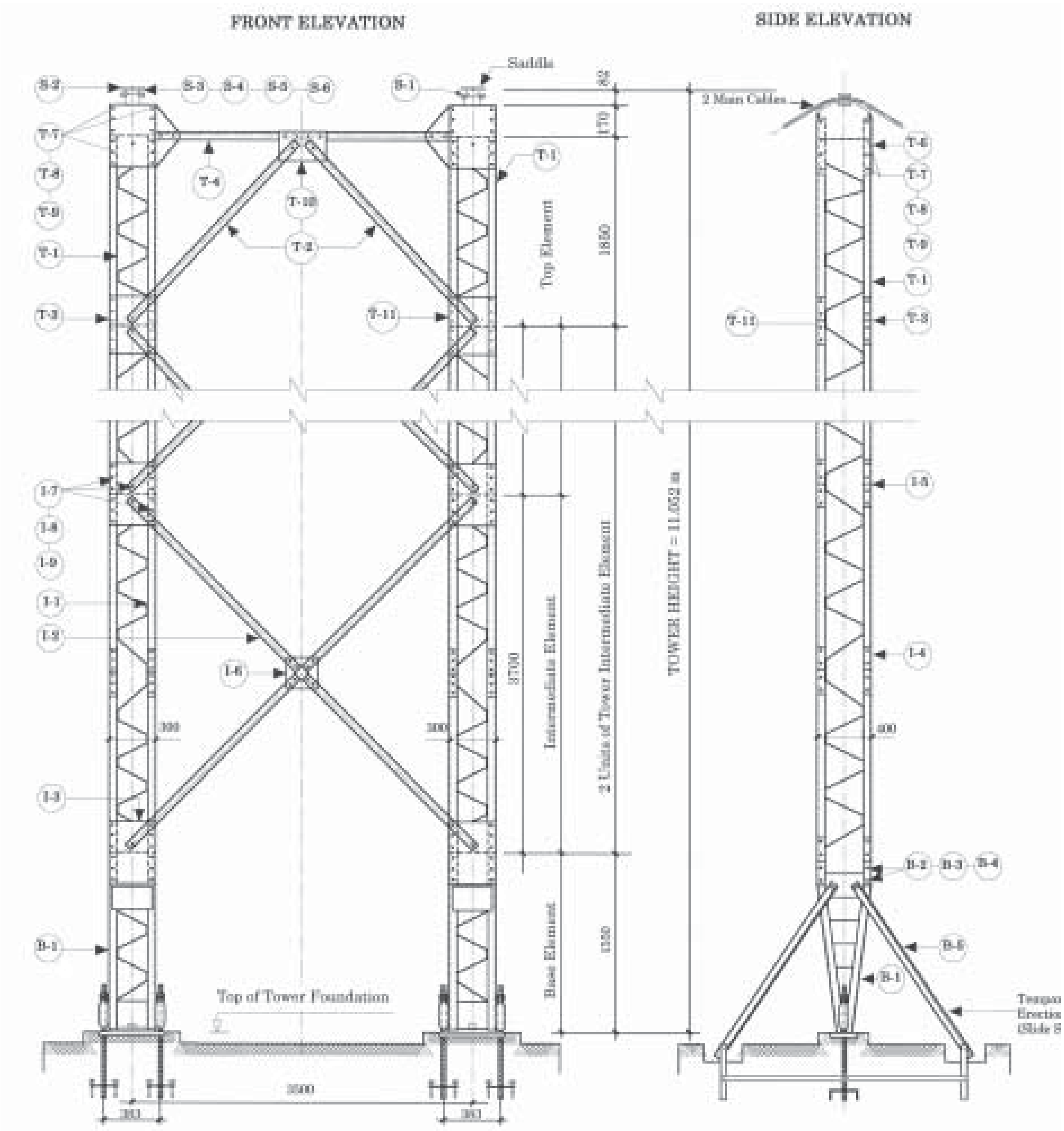
Type of element	Part Nos. in Steel Drawing
Base Element	**B**
Intermediate Element	**I**
Top Element	**T**
Saddle	**S**

Retighten all Nuts and Bolts firmly after fixing the Elements.

After the bridge has been erected, the cable clamps on the top of the pylon must be firmly tightened, and then all the side struts (angles) must be removed.

Temporary fixation of Tower Base with side Struts



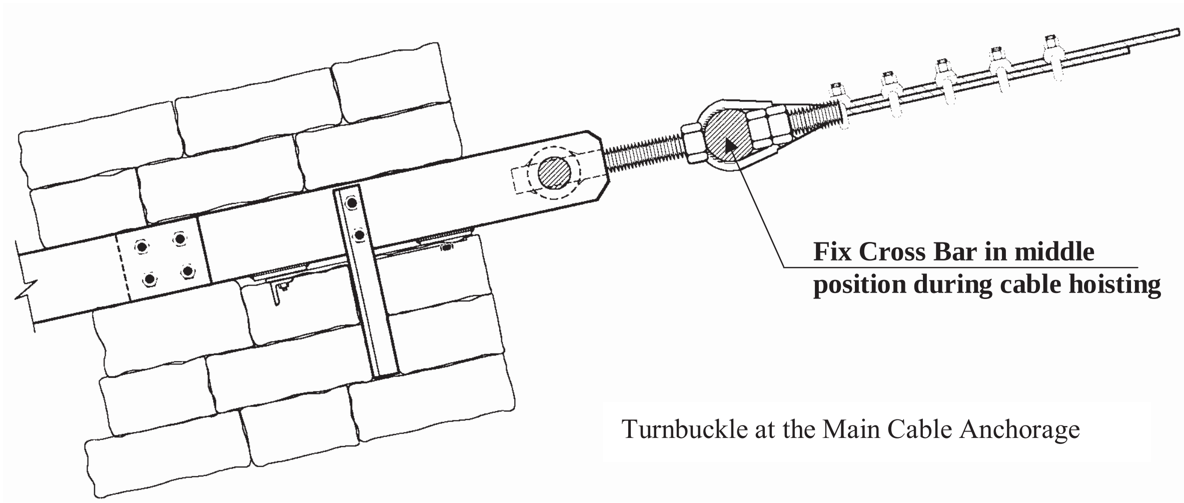


Assembly and Layout of Tower No. 4

6.7.2 HOISTING OF MAIN CABLES AND SAG SETTING

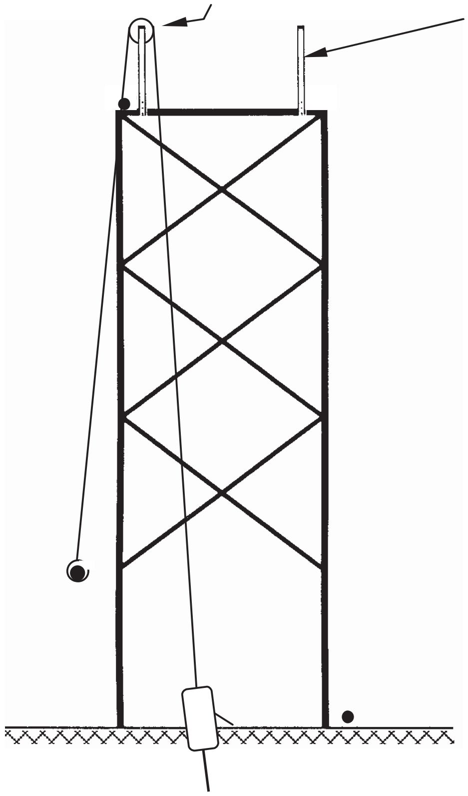
Usually, the main cables are pulled across the river with the help of nylon ropes. In case of a deep or turbulent river, attach an empty airtight plastic can (jerry can) at the end of the cable. This will prevent the cable-end from getting stuck between stones and rocks lying on the riverbed.

Make sure that the respective Main Cables are pulled on either side of the Tower and Walkway Foundations. Fix them temporarily at the respective Turnbuckle at the Main Cable Anchor.



Turnbuckle at the Main Cable Anchorage

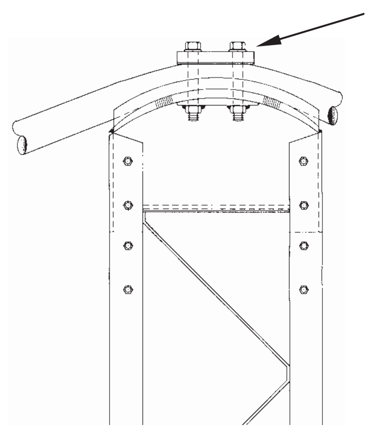
Fix a pulley block



Temporary device for lifting the main cables (supplied with Top Element)

Lift the cables one by one, first the inner then the outer cables.

Once the cables are in the saddle groove, immediately secure them with the saddle cover plate, but do not tighten the bolts so that the cables can still slide during erection time.



Keep saddle cover plate loose during bridge erection time, but tighten it firmly before removing the temporary side struts at the bottom of the tower.

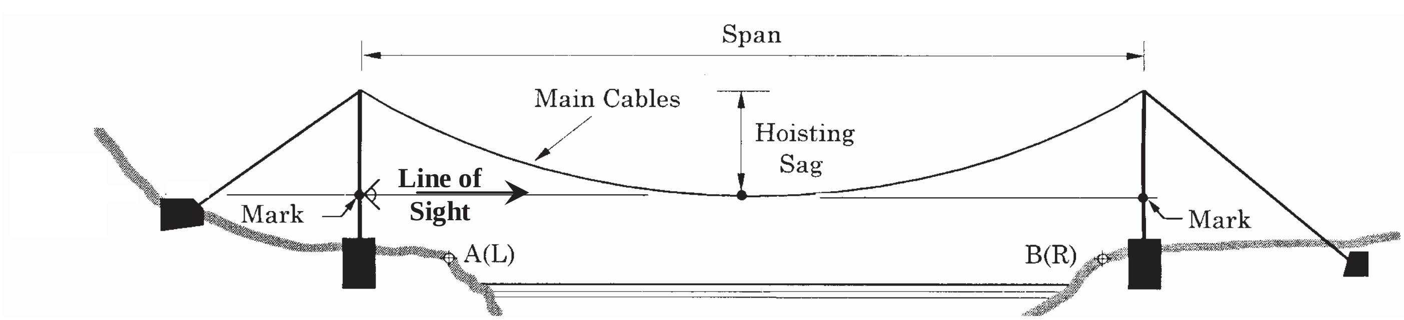
Main Cables at either side of the Tower

The hoisting sag setting of the Main Cables is one of the most important tasks during the erection of the bridge.

The towers should stand exactly vertical, the saddle cover plates are loose, and the temporary side struts are fixed. With this arrangement, the main cables can slide over the saddles when the bridge is being erected and the cables become longer; and the towers remain in vertical position in dead load.

With a leveling instrument, the exact hoisting sag is fixed in the following way:

- Mark the elevation of the hoisting sag on both the towers with permanent paint.
- Now set up the leveling instrument on the tower foundation so that its line of sight matches with the mark on the tower across the river. Setting up the leveling instrument at the prescribed hoisting sag elevation has to be done by trial and error, and may require several attempts. Make use of the three adjustment wheels of the leveling instrument when the eyesight is close to the mark.
- Pull the Main Cables until they reach a level of about 20 cm higher than the hoisting sag.
- Clamp the cables around the thimbles at the cross bar of the Turnbuckle of the main cable anchorage. Make sure that the crossbar is **in the middle position** of the threaded anchor bars when clamping the main cables, secured with two nuts in the front and one in the back (see page 135).
- The Main Cables should be left in this "over pulled" position for at least 12 hours so that some relaxation can take place.
- Now move the Turnbuckles to achieve the exact sag setting. For compensating elongations due to change in air temperature, recheck the hoisting sag at different times of the day and make the necessary adjustments. It is recommended to adjust the final sag setting during the hot day after noon, when the cables have accumulated maximum heat, i.e., during maximum elongation condition.
- The hoisting sags of all the Main Cables must be identical at any point of time.



Also check the sags from time to time when the fitting works are going on. Different elongations may take place due to dissimilar hidden cable relaxations when the tension increases. Adjust possible sag differences with the help of the turnbuckles at the main cable anchor so that the Main Cables are always parallel and compare the dead load sag with the pre-calculated values.

6.7.3 HOISTING OF SPANNING CABLES

Fix the Spanning Cables at the Turnbuckles of the Tower and Walkway Anchorage on one river bank. Make sure that the crossbar of the turnbuckles are at the **outermost position** secured with two nuts each so that more tension can be applied when all the fitting work is completed.
Pull the cables across the river and secure them at the corresponding turnbuckles on the other bank (crossbar at the outermost position).

It is not necessary to achieve the sag corresponding to the required dead load camber, since this requires very high pulling forces. Just make sure that both the Spanning Cables are hanging approximately parallel and are high enough over the highest water-level of the river.
It is much easier to adjust the spanning cables when the suspender is being fitted (see Chapter 6.7.4).

6.7.4 FITTING SUSPENDERS AND CENTER ROW OF STEEL DECK

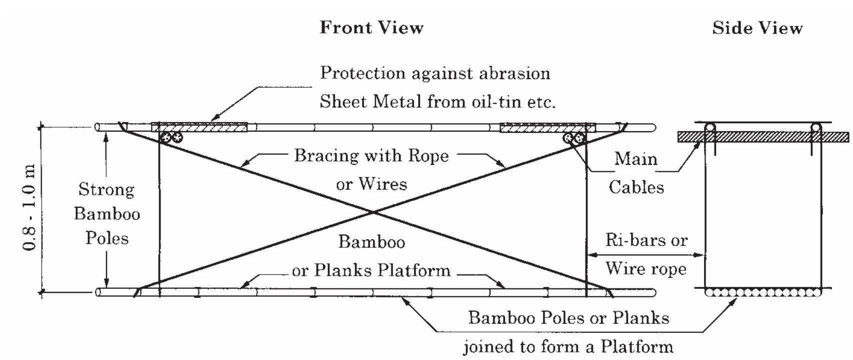
Fitting the suspenders and walkway elements is the most difficult and daring job.
As mentioned already in the beginning of this Chapter 6.7, adequate safety precautions should be strictly followed and the respective responsibilities should be clarified.

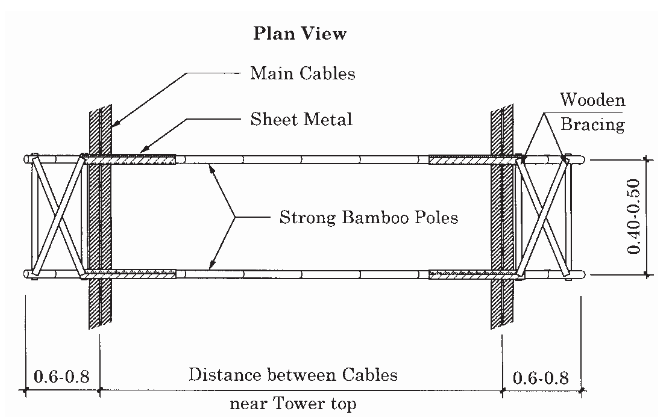
The suspender fitting work should start from **both** the towers and proceed towards the center of the bridge. This procedure is easier and has more advantages than starting the fitting work from the center. However, in order to achieve a proper symmetry of the suspenders, the **central suspender** must be fitted first.

The only disadvantage will arise when finishing the fitting works at the middle of the bridge. Due to inaccuracies, the remaining spacing at the center of the bridge might be either too long or too short. For minimizing this imprecision, the required distances to the towers and the center have to be rechecked after fitting 10 suspenders.

Preparation for Suspender Fitting Works:

- Lay out all the suspenders in sequence on the ground.
- Prepare all crossbeams, J-hooks and steel deck.
- Prepare two fitter platforms, one for the main cables and one for the spanning cables, and two gauged sticks of exactly 1.00m length.



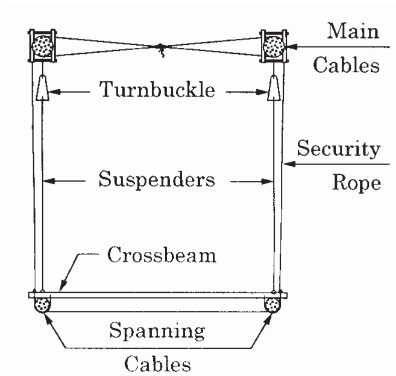


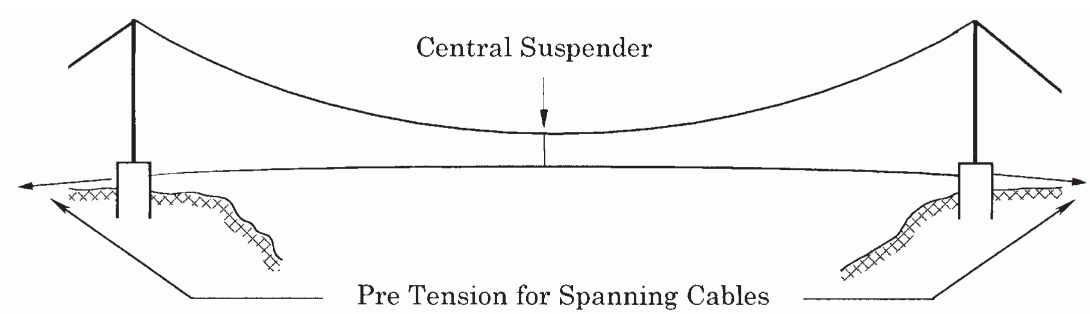
Assembly:
First fit the top portion on the main cables, then hang the platform under this by using either steel bars or cables.

Fitting the Central Suspender :

With the help of the fitting platform, the suspender in the center has to fitted first. Determine and reconfirm the center with a tape and level instrument, then fit the first suspender-pair at the center of the bridge. To avoid excessive load on the center suspender during erection time, bind all cables (spanning and main cables) together as shown in the sketch below with a security rope.

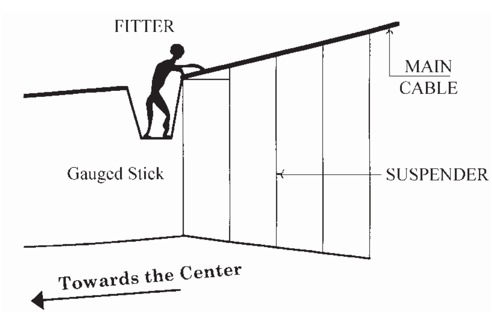
The **security rope** supports the suspender in the middle during erection work.

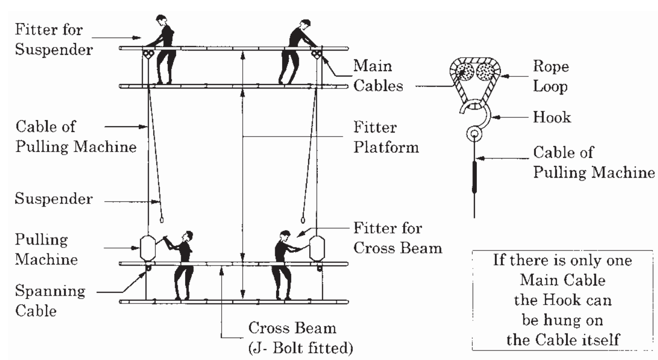




Tighten the spanning cable to some extent; now the cables are ready to be fixed to the suspenders.

Sketches and Procedures for Fitting Operations:





- Start the fitting work from both sides of the bridge and work towards the center of the bridge;
- Fix one cable car on top of the main cables and one on top of the spanning cables;
- Fix the first two suspenders to the main cables at the prescribed distance from the tower;
- Lift the spanning cable until the suspenders can be connected with the threaded rod of the walkway crossbeam.

Note: The first crossbeam at the bridge entrance is fitted without a suspender (see Drw. No. 19Ncon).

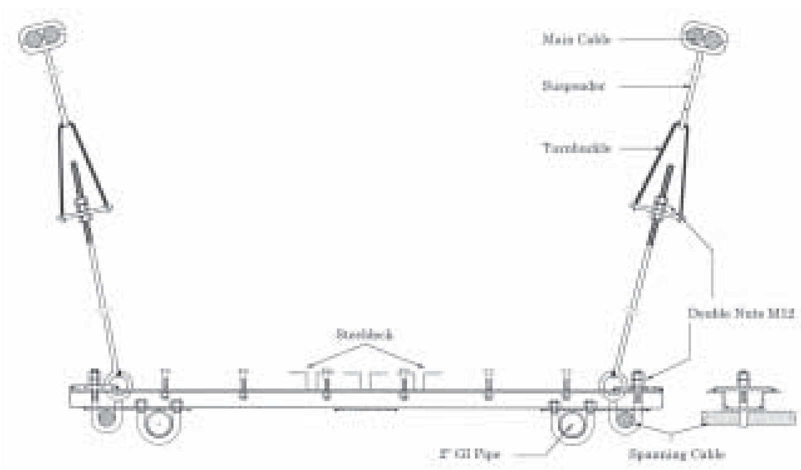
- In order that the suspenders are fixed exactly 1m apart, use gauged sticks for exact fitting;
- Re-adjust the spanning cables from both the banks as the suspenders are being fitted;
- After fitting ten pairs of suspenders, check the distances to the tower and to the center;
- Adjust only inaccuracies by moving the crossbeams;
- Gradually start fitting the **center row only** with standard steel deck panels as shown in Drawing No. 19 Ncon.

When the center is reached, there will be some extra length of spanning cable. For adjusting this, pull the spanning cables from both the banks with the tirefor machine through the loose J-hooks. Make sure that the middle row of the steel deck is fitted when doing this work.

- When all the suspenders have been fixed, tighten the spanning cables with the cable pulling machine as much as possible before fitting the 2" G.I. pipes below the crossbeams and before fitting the rest of the steel deck panels.
- Fix the handrail cables by pulling them through the suspender-rings just above the suspender turnbuckle, and secure them to the handrail posts by winding the cable end twice around the post.

Fitting the 2" G.I. Pipes :

Two 2" G.I. pipes have to be mounted from below to the steel deck cross beams. This provides additional vertical but also lateral stability to the entire walkway. These pipes can also be used for transferring water across the river as per local requirement.



The G.I. pipes have to be fitted before the outer rows of the steel decks are mounted in the following way:

- Lay two pipes of 6m length end to end on the ground and join them together firmly. Use a 2" die set and jute threads to make the joint water tight.
- In the same way, also fix half of the "union" at each end of the 12m piece.
- Now carry the 12m pipe to the bridge, pass it through the suspenders by securing it with nylon ropes until the entire 12m piece is on the outside of the suspenders.
- Now bring the pipe into proper position underneath the walkway, and secure it immediately with the U-clamps and join it with the "union".
- In case a union coincides with a crossbeam, cut the pipe and make a new thread with the die set.

This work requires special attention. While passing the pipe outside the suspenders, several workers are necessary and sufficient ropes are required to secure the pipe at all times.

APPENDIX N: COST ESTIMATE

Footbridge Overall Cost Estimate

Overall Estimate		
Item	Total Cost	Actual Cost (Donations Subtracted)
Materials	$40,417.77	35,381.15
Labor	$22,028.00	$2,720.00
Equipment	$4,625.97	$4,625.97
Total	**$67,071.74**	**$42,727.12**

Site Preparation Estimate

Material Estimate							
Material Description	# of Material Units	Price/Unit	Cost of Materials	Transportation Costs	Total Cost	Donated?	Actual Cost
2"x6"x12' lumber (ea.)	36	$1.80	$64.80	$125.00	$189.80	N	$189.80
4'x8' Corrugated Plastic (ea.)	23	$6.20	$142.60	$125.00	$267.60	N	$267.60
16-D Nails (lb)	10	$2.00	$20.00	0	$20.00	N	$20.00

Labor Estimate							
Labor Description	# of Laborers	Hrs/Laborer	Wage of Laborer	Cost of Labor	Total Cost	Donated?	Actual Cost
Surveyor (P.M.)	1	8	$10.00	$80.00	$80.00	N	$80.00
Site Clearing	10	56	$2.50	$1,400.00	$1,400.00	Y	$0.00
Carpentry	10	8	$2.50	$200.00	$200.00	Y	$0.00
Horse	1	56	$0.50	$28.00	$28.00	Y	$0.00

Equipment Estimate							
Equipment Description	# of Equipment Units	Price/Unit	Cost of Equipment	Transportation Costs	Total Cost	Donated?	Actual Cost
Chainsaw	1	$300.00	$300.00	$0.00	$300.00	N	$300.00
Survey Equipment	1	$300.00	$300.00	$0.00	$300.00	N	$300.00
Axes	3	$18.00	$54.00	$0.00	$54.00	N	$54.00
Machetes	8	$3.50	$28.00	$0.00	$28.00	N	$28.00
Tow chains/straps	1	$65.00	$65.00	$0.00	$65.00	N	$65.00
Hammers (16 oz.)	8	$8.79	$70.32	$0.00	$70.32	N	$70.32

Total $1,374.72

Foundation Estimate

Material Estimate							
Material Description	# of Material Units	Price/Unit	Cost of Materials	Transportation Costs	Total Cost	Donated?	Actual Cost
Cement (42.5kg bag)	687	$8.00	$5,496.00	$595.00	$6,091.00	N	$6,091.00
Sand (m^3)	70	$13.90	$973.00	$700.00	$1,673.00	N	$1,673.00
Gravel (ton)	141	$15.95	$2,248.95	$805.00	$3,053.95	N	$3,053.95
Masonry Block (yd^3)	75	$25.00	$1,875.00	$595.00	$2,470.00	N	$2,470.00
#3 Steel Rebar (ft)	394	$0.18	$70.92	$35.00	$105.92	N	$105.92
#5 Steel Rebar (ft)	180	$0.33	$59.40	$35.00	$94.40	N	$94.40
3/4" Plywood (4'x8' sheets)	4	$9.50	$38.00	$0.00	$38.00	N	$38.00
2"x6"x12' lumber (ea.)	4	$1.80	$7.20	$0.00	$7.20	N	$7.20
Nails 16-D (lb)	5	$2.00	$10.00	$0.00	$10.00	N	$10.00
Tie-wire (100-lb)	1	$31.00	$31.00	$0.00	$31.00	N	$31.00
Form oil (gal)	2	$19.75	$39.50	$0.00	$39.50	N	$39.50
Steel Assembly*	1	$936.65	$936.65	$125.00	$1,061.65	N	$1,061.65

Labor Estimate							
Labor Description	# of Laborers	Hrs/Laborer	Wage of Laborer	Cost of Labor	Total Cost	Donated?	Actual Cost
Excavating	10	96	$2.50	$2,400.00	$2,400.00	Y	$0.00
Bricklayers	10	160	$2.50	$4,000.00	$4,000.00	Y	$0.00
Concrete Mixers	4	64	$2.50	$640.00	$640.00	Y	$0.00
Concrete Pourers	4	64	$2.50	$640.00	$640.00	Y	$0.00
Backfilling/Grading	2	24	$2.50	$120.00	$120.00	Y	$0.00
Steel Assembly/Finish Work	10	32	$2.50	$800.00	$800.00	Y	$0.00
Project Manager	1	32	$10.00	$320.00	$320.00	N	$320.00

Foundation Estimate Cont.

Equipment Estimate							
Equipment Description	# of Equipment Units	Price/Unit	Cost of Equipment	Transportation Costs	Total Cost	Donated?	Actual Cost
Metal Hacksaw	2	$11.50	$23.00	$0.00	$23.00	N	$23.00
Replacement blade	12	$2.75	$33.00	$0.00	$33.00	N	$33.00
Wheel barrow	4	$78.00	$312.00	$0.00	$312.00	N	$312.00
Chute	1	$27.00	$27.00	$0.00	$27.00	N	$27.00
Metal Bucket	6	$8.50	$51.00	$0.00	$51.00	N	$51.00
Pick axes	2	$26.00	$52.00	$0.00	$52.00	N	$52.00
Sledge Hammer	2	$28.50	$57.00	$0.00	$57.00	N	$57.00
Spade Shovels	8	$16.80	$134.40	$0.00	$134.40	N	$134.40
Hand Trowels	2	$13.50	$27.00	$0.00	$27.00	N	$27.00
Level (Plumb-Bob)	1	$6.50	$6.50	$0.00	$6.50	N	$6.50
Measuring Tape	2	$14.40	$28.80	$0.00	$28.80	N	$28.80
Water Pump (ea., 2" outlet)	1	$494.00	$494.00	$0.00	$494.00	N	$494.00
Pionjar Chisel/Vibrator (month)	2	$231.63	$463.26	$0.00	$463.26	N	$463.26
						Total	**$16,704.58**

*Includes cost of material and labor for fabrication. See Foundation Steel Components Estimate.

Anchorage Estimate

Material Estimate							
Material Description	# of Material Units	Price/Unit	Cost of Materials	Transportation Costs	Total Cost	Donated?	Actual Cost
Cement (42.5kg bag)	352	$8.00	$2,816.00	$315.00	$3,131.00	N	$3,131.00
Sand (m^3)	32	$13.90	$444.80	$315.00	$759.80	N	$759.80
Gravel (ton)	106	$15.95	$1,690.70	$350.00	$2,040.70	N	$2,040.70
3/4" Plywood (4'x8' sheets)	4	$9.50	$38.00	$0.00	$38.00	N	$38.00
2"x6"x12' lumber (ea.)	4	$1.80	$7.20	$0.00	$7.20	N	$7.20
Nails 16-D (lb)	5	$2.00	$10.00	$0.00	$10.00	N	$10.00
Form oil (gal)	1	$19.75	$19.75	$0.00	$19.75	N	$19.75
Steel Assembly*	1	$2,359.19	$2,359.19	$215.00	$2,574.19	N	$2,574.19

Labor Estimate							
Labor Description	# of Laborers	Hrs/Laborer	Wage of Laborer	Cost of Labor	Total Cost	Donated?	Actual Cost
Excavating	10	64	$2.50	$1,600.00	$1,600.00	Y	$0.00
Formwork	4	16	$2.50	$160.00	$160.00	Y	$0.00
Concrete Mixers	4	48	$2.50	$480.00	$480.00	Y	$0.00
Concrete Pourers	4	48	$2.50	$480.00	$480.00	Y	$0.00
Backfilling/Grading	2	32	$2.50	$160.00	$160.00	Y	$0.00
Steel Assembly	10	32	$2.50	$800.00	$800.00	Y	$0.00
Project Manager	1	48	$10.00	$480.00	$480.00	N	$480.00

Equipment Estimate							
Equipment Description	# of Equipment Units	Price/Unit	Cost of Equipment	Transportation Costs	Total Cost	Donated?	Actual Cost
Wood Handsaw	4	$16.49	$65.96	$0.00	$65.96	N	$65.96
Wrench set	2	$47.80	$95.60	$0.00	$95.60	N	$95.60
Framing square	2	$18.00	$36.00	$0.00	$36.00	N	$36.00

Total $9,258.20

*Includes cost of material and labor for fabrication. See Anchorage Steel Components Estimate.

Tower Estimate

Material Estimate							
Material Description	# of Material Units	Price/Unit	Cost of Materials	Transportation Costs	Total Cost	Donated?	Actual Cost
Base Assembly*	1	$411.76	$411.76	$215.00	$626.76	N	$626.76
Intermediate Assembly*	1	$2,433.67	$2,433.67	$0.00	$2,433.67	N	$2,433.67
Top Assembly*	1	$249.55	$249.55	$0.00	$249.55	N	$249.55
Saddle Assembly*	1	$239.76	$239.76	$0.00	$239.76	N	$239.76
Anti-Corrosion Paint (gal)	3	$27.95	$83.85	$0.00	$83.85	N	$83.85

Labor Estimate							
Labor Description	# of Laborers	Hrs/Laborer	Wage of Laborer	Cost of Labor	Total Cost	Donated?	Actual Cost
Assemble Towers	10	32	$2.50	$800.00	$800.00	Y	$0.00
Tower Erection	10	32	$2.50	$800.00	$800.00	Y	$0.00
Project Manager	1	64	$10.00	$640.00	$640.00	N	$640.00

Equipment Estimate							
Equipment Description	# of Equipment Units	Price/Unit	Cost of Equipment	Transportation Costs	Total Cost	Donated?	Actual Cost
High Test Chains/Hooks	4	$154.78	$619.12	$0.00	$619.12	N	$619.12
Pulley Blocks (5 ton)	2	$39.99	$79.98	$0.00	$79.98	N	$79.98
Pulley Machine (3.2 ton)	1	$249.99	$249.99	$0.00	$249.99	N	$249.99

Total **$5,222.68**

*Includes cost of material and labor for fabrication. See Tower Steel Components Estimate.

Main and Spanning Cables, Suspenders, and Walkway Estimate

Material Estimate							
Material Description	# of Material Units	Price/Unit	Cost of Materials	Transportation Costs	Total Cost	Donated?	Actual Cost
Main Cable (ft), d=1 3/8"	594	$5.23	$3,106.62	$0.00	$3,106.62	Y	$0.00
Spanning Cable (ft), d=1"	386	$2.96	$1,142.56	$0.00	$1,142.56	Y	$0.00
Fixiation and Handrail Cables, d=1/2"	772	$1.02	$787.44	$0.00	$787.44	Y	$0.00
Wire Rope Thimbles	1	$79.68	$79.68	$4,487.00	$4,566.68	N	$4,566.68
Bulldog Grips	1	$308.68	$308.68	$0.00	$308.68	N	$308.68
Suspenders Steel Assembly*	1	$1,035.23	$1,035.23	$125.00	$1,160.23	N	$1,160.23
Walkway Steel Assembly*	1	$245.91	$245.91	$90.00	$335.91	N	$335.91
Lumber (2"x6"x8' ea.)	177	$1.20	$212.40	$125.00	$337.40	N	$337.40
Wire Mesh netting (4'x12' ea.)	31	$37.00	$1,147.00	$90.00	$1,237.00	N	$1,237.00
3" Deck Screws (lb)	25	$2.72	$68.00	$0.00	$68.00	N	$68.00

Labor Estimate							
Labor Description	# of Laborers	Hrs/Laborer	Wage of Laborer	Cost of Labor	Total Cost	Donated?	Actual Cost
Hoisting Main Cables	10	24	$2.50	$600.00	$600.00	Y	$0.00
Hoisting Spanning Cables	10	8	$2.50	$200.00	$200.00	Y	$0.00
Suspenders Set-up	10	32	$2.50	$800.00	$800.00	Y	$0.00
Suspenders Installation	10	40	$2.50	$1,000.00	$1,000.00	Y	$0.00
Walkway Installation	10	48	$2.50	$1,200.00	$1,200.00	Y	$0.00
Project Manager	1	120	$10.00	$1,200.00	$1,200.00	N	$1,200.00

Main and Spanning Cables, Suspenders, and Walkway Estimate Cont.

Equipment Estimate							
Equipment Description	# of Equipment Units	Price/Unit	Cost of Equipment	Transportation Costs	Total Cost	Donated?	Actual Cost
Come Along (2 ton)	4	$24.99	$99.96	$90.00	$189.96	N	$189.96
Rope (100ft)	4	$9.99	$39.96	$0.00	$39.96	N	$39.96
Hooks	4	$4.79	$19.16	$0.00	$19.16	N	$19.16
Pulley Machine (1760 lb)	4	$149.00	$596.00	$0.00	$596.00	N	$596.00
Pulley Blocks (4 ton)	4	$19.99	$79.96	$0.00	$79.96	N	$79.96
Screwdrivers	8	$3.50	$28.00	$0.00	$28.00	N	$28.00

Total $10,166.94

*Includes cost of material and labor for fabrication. See Suspenders and Walkway Steel Components Estimate.

Foundation General Material Calculations

CONCRETE

Material	Total Volume (m^3)	Cement (42.5 kg bags)	Sand (m^3) Required	Gravel (m^3) Required
Plumb Concrete	56.4	175	15.79	30.46
Lean Concrete	2.41	9	0.72	1.21
Reinforced Concrete	9.82	74	4.47	8.35
Block Stone	28.41	85	14.21	n/a
TOTAL of Foundation		344	35.19	40.01
TOTAL for Both Foundations	**Block Stone (yd^3)**	**Cement (42.5 kg bags)**	**Sand (m^3)**	**Gravel (ton)**
	75	687	70	141

REINFORCEMENT

Type of Re-Bar	# 3 Re-Bar (ft)	# 5 Re-Bar (ft)
TOTAL of Foundation	197	90
TOTAL for Both Foundations	394	180
Also: 100 lb Tie-Wire		

FORMWORK

	Total Area (ft^2)	Plywood (4'x8'x3/4")	Lumber (2"x6"x12')	Nails, 16-D (lb)
TOTAL of Foundation	130	4.0625	3.375	3
TOTAL for Both Foundations		4	4	3
Also: 1 gal Form-Oil				

Foundation Steel Components Estimate

Part No.	Description (mm)	Quantity	Quantity for Bridge	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (lb)
1a	Angle 80/80/8, l=400	2	4	5	8	4.8	28.2
1b	Flat 40/6, l=1200	2	4	0.52	0	4.8	18
1c	Rod d=32, l=1270	1	2	0.2	0	2.4	34
1d	Plate d=60, t=6	2	4	0	4	0	0.8
2	Rod d=16, l=630 (50 mm M16 thread)	4	8	0	0	0	17.6
3	Rod d=16, l=155 (25 mm M16 thread)	14	28	0	0	2.8	14
4a	Plate 150/110/6	12	24	8.64	24	9.6	38.4
4b	Plate 230/200/6	4	8	5.2	0	0	32
4c	Channel ISMC 75-2450	4	8	1.92	40	32	256
4d	Rod d=24, l=150	4	8	0.56	0	0.8	8.8
4e	Open Thimble (13mm)	4	8	0	0	0	0
4f	Plate 100/60/6	4	8	2.08	8	0.8	4
5	Channel ISMC 200-505	2	4	2.6	8	0	88
6a	Rod d=32, l=830 (90 mm M30 thread)	4	8	0	0	0	88
6b	Plate 60/60/20	4	8	1.6	8	0	7.2
7	Hexagonal nut M30	17	34	0	0	0	17
8	Plate d=70, t=16	5	10	0	10	0	7.5

Foundation Steel Components Estimate (Continued)

Part No.	Description (mm)	Quantity	Quantity for Bridge	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (lb)
9a	Plate 505/250/32	2	4	3.2	8	12	260
9b	Plate 325/30/32	2	4	0.36	0	1.2	20
9c	Square bar 20, l=50	2	4	0.26	0	0	2
10	Rod d=16, l=171 (30 mm M16 thread)	5	10	0	0	0	5.5
11a	Plate 500/160/6	2	4	2.4	24	0	28.8
11b	Channel ISMC 75-500	4	8	2	0	0	60.8
11c	Plate 150/90/6	2	4	1.16	8	0	5.2
11d	100/90/6	4	8	2.32	16	0	7.2
12a	Rod d=25, l=1400 (M24 threads)	4	8	0	0	0	88
12b	Flat 50/6, l=50	4	8	1.28	8	0	1.6
13	Angle 50/50/6, l=395	4	8	1.28	16	0	30.4
14	Rod d=16, l=147 (30 mm M16 thread)	5	10	0	0	0	2.5
15	Rod d=62, l=150	2	4	2.624	0	1.2	22
16	Angle 50/50/6, l=1200	2	4	0.64	24	0	46
17	Angle 50/50/6, l=1811	1	2	0.32	32	0	34
18	Flat 40/6, l=1020	1	2	0.26	8	0	8.6

Foundation Steel Components Estimate (Continued)

Part No.	Description (mm)	Quantity	Quantity for Bridge	Cuts (ft)	Drills (ea.)	Paint (ft²)	Weight (lb)
19a	Rod d=16, l=976 (35mm M16 thread)	2	4	0	0	2	12.8
19b	Washer d=18, IS 6610	4	8	0	0	0	4.4
20a	Angle 40/40/6, l=330	4	8	1.2	8	0	20
20b	Angle 40/40/6, l=60	4	8	1.2	8	0	3.6
21	Rod d=20, l=1723	2	4	0.28	0	0.4	36
22	Hexagonal nut M16 IS 1363	65	130	0	0	0	7.8
23	Washer d=18, IS 6610	15	30	0	0	0	1.8
24	Hexagonal Screw M16x40, IS 1363	21	42	0	0	0	8.82
25	Hexagonal nut M24, IS 1363	21	42	0	0	0	9.24
26	Bulldog Grip d=13	13	26	0	0	0	0
27	Bulldog Grip d=26	10	20	0	0	0	0
28	Open Thimble (26mm)	2	4	0	0	0	0

FASTENING HARDWARE
CABLE FIXATION HARDWARE

	Cuts (ft)	Drills (ea.)	Paint (ft²)	Weight (lb)
TOTALS	**49**	**270**	**75**	**1,387**

Foundation Welding Details

Part No.	Description (in mm)	Quantity	Quantity for Bridge	Welds (ft)
1	6 (1/4") fillet	1	2	5
4	6 (1/4") fillet	2	4	117.04
6	6 (1/4") fillet	1	8	2.36
9	6 (1/4") fillet	1	8	16.96
9	12 (1/2") fillet	1	4	10.88
11	4 (1/8") fillet	1	4	24.24
12	4 (1/8") fillet	1	8	2.36
19	6 (1/4") fillet	2	4	2.36
20	4 (1/8") fillet	1	8	1.52
TOTAL				**182.72**

Cost of Steel :
$1100/ton

Cost of Fabrication:	
Cutting - (320 ft/day)	3 steelworkers @ $2.50/hour per steelworker, 8 hour workday
Drilling - (300 ea./day)	
Painting - (1.1 tons/day)	
Welding -(150 ft/day)	

	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (ton)	Welds (ft)
Totals	49	270	75	0.69	183
Labor Costs	$9.21	$54.00	$37.64		$73.20
Time (days)	0.15	0.90	0.63		1.22

Cost		**Time Required for Fabrication (Days)**
Material	**Labor**	
$762.61	$174.04	2.9
TOTAL Foundation Assembly Cost		
$936.65		

Anchorage General Material Calculations

CONCRETE

Type of Concrete	Total Volume (m^3)	Cement (42.5 kg bags)	Sand (m^3)	Gravel (m^3)
Plumb Concrete	55.39	172.03	15.51	29.91
Lean Concrete	0.38	4.08	0.11	0.19
TOTAL	55.77	176.11	15.62	30.10
TOTAL for Both Anchors	**Block Stone (m^3)**	**Cement (42.5kg bags)**	**Sand (m^3)**	**Gravel (ton)**
	n/a	**352**	**32**	**106**

FORMWORK

	Total Area (ft^2)	Plywood (4'x8'x3/4")	Lumber (2"x6"x12')	Nails, 16-D (lb)
TOTAL	244	7.625	3.20833333	3
TOTAL for Both Anchors		**Plywood (4'x8'x3/4")**	**Lumber (2"x6"x12')**	**Nails, 16-D (lb)**
		4	**4**	**3**
Also: 1 gal form-oil				

Anchorage Steel Components Estimate

Part No.	Description (in mm)	Quantity	Quantity for Bridge	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (lb)
1a	Flat 80/6, l=500	4	8	2.08	48	6.4	40.8
1b	Flat 160/10, l=1100	8	16	8.32	128	57.6	440
1c	IS Square bar 80 l=150	4	8	6	8	3.2	88.8
1d	Rod d=10, l=110	8	16	0.48	0	0	27.2
1e	Rod d=45, l=1000 (600mm M45 thread)	4	8	0	0	0	188
1f	Hexagonal Nut M45	4	8	0	0	0	1.2
2	Flat 40/6, l=460	4	8	1.04	32	0	13.6
3a	Channel ISMC 200-500	4	8	5.28	8	20	186.4
3b	Plate 183/60/10	8	16	9.6	0	4.8	4.8
3c	Plate 480/180/8	4	8	4.72	8	6.4	88
3d	Plate 200/66/10	8	16	10.4	0	4.8	35.2
3e	Plate 220/100/12	8	16	5.12	16	4.8	59.2
4	Pin d=90, l=180	2	4	1.08	0	0	70
5	Split pin d=8, l=150	4	8	0	0	0	0.96
6a	Channel ISMC 125-1000	8	32	13.12	320	0	864
6b	Plate 120/120/6	8	32	12.8	128	0	44.8
7	Flat 40/6, l=1160	4	8	1.04	32	0	37.6
8	Angle 50/50/6, l=530	4	8	1.28	48	0	48.8
9	Flat 100/10, l=1700	16	32	10.56	256	0	928
10	Angle 50/50/6, l=1500	2	4	0.64	24	0	66
11	Angle 50/50/6, l=1490	2	4	0.64	28	0	58
12	Angle 50/50/6, l=1400	2	4	0.64	28	0	54
13	Hexagonal Nut M45	13	26	0	0	0	54.6
14	Hexagonal Bolt M12x40 IS 1363	75	150	0	0	0	18
15	Hexagonal bolt M16x60 IS 1363	100	200	0	0	0	60
16	Hexagonal nut M12 IS 1363	75	150	0	0	0	5.7
17	Hexagonal nut M16 IS 1363	100	200	0	0	0	14
18	Plain washer d=17	100	200	0	0	0	7
19	Rod d=25, l=2650	2	4	0.36	0	0	98

FASTENING HARDWARE

CABLE FIXATION HARDWARE

	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (lb)
TOTALS	**95**	**1112**	**108**	**3603**

Anchorage Welding Details

Part No.	Description (in mm)	Quantity	Quantity for Bridge	Welds (ft)
1	6 (1/4") fillet	2	4	15.2
3	6 (1/4") fillet	2	4	30.4
3	8 (3/8") fillet	2	4	3.52
6	6 (1/4") fillet	16	32	52.48
Total				**101.6**

Cost of Steel :
$1100/ton

Cost of Fabrication:	
Cutting - (320 ft/day)	3 steelworkers @ $2.50/hour per steelworker, 8 hour workday
Drilling - (300 ea./day)	
Painting - (1.1 tons/day)	
Welding -(150 ft/day)	

	Paint (ft^2)	Cuts (ft)	Drills (ea.)	Welds (ft)
Totals	102	95	1112	108
Labor Costs	$40.80	$17.81	$222.40	$98.18
Time (days)	0.68	0.30	3.71	1.64
Weight (ton)	1.8			

Cost		**Time Required for Fabrication (Days)**
Material	**Labor**	
$1,980.00	$379.19	6.32
TOTAL Anchorage Assembly Cost		
$2,359.19		

Total Tower Fabrication Costs

Total

	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (tons)	Welding (ft)
TOTAL	**152.83**	**1968**	**891.50**	**2.44**	**518.34**
COST ($)	**28.66**	**393.60**	**133.02**	**2682.52**	**207.34**
Time (days)	0.48	2.19	2.22		3.46
			Total Tower Steel Assembly Cost	**$3,334.74**	

Base Element

	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (tons)	Welding (ft)
TOTALS	**44.05**	**80**	**110.83**	**0.31**	**147.00**
	Tower Base Steel Assembly Cost			**$411.76**	

Intermediate Element

	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (tons)	Welding (ft)
TOTALS	**56.69**	**1504**	**674.23**	**1.81**	**220.68**
			Tower Intermediate Steel Assembly Cost	**$2,433.67**	

Top Element

	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (tons)	Welding (ft)
TOTALS	**2.56**	**232.00**	**60.98**	**0.17**	**32.72**
	Tower Top Steel Assembly Cost			**$249.55**	

Saddle

	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (tons)	Welding (ft)
TOTALS	**49.53**	**152**	**45.46**	**0.15**	**117.94**
	Tower Saddle Steel Assembly Cost			**$239.76**	

Tower Base Components Estimate

Part No.	Description (in mm)	Quantity	Quantity for Bridge	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (lb)
B-1a	Angle 65/65/6 l = 1551.5	8	16	18.1	80	66.1	311.5
B-1b	Rod ø 14 mm l = 1461	4	8	0	0	0.0	31.2
B-1c	Plate 270/200/6	4	8	7.1	0	9.3	43.9
B-1d	Plate 200/197.5/6	4	8	5.2	0	6.8	29.1
B-1e	Plate 250/103.5/6	4	8	2.7	0	4.5	15.7
B-1f	Plate 388/60/6	8	16	3.1	0	8.0	38.4
B-1g	Plate 60/48/6	4	8	1.6	0	0.5	2.3
B-1h	Plate 240/150/6	2	4	2.0	0	3.1	15.0
B-1i	Plate 334.5/150/6	4	8	3.0	0	8.6	94.9
B-1j	IS heavy tube O.D. ø 48.3 l=150	4	8	1.3	0	4	11.6
B-2	Friction grip bolt M 16 x 50 IS 3757-8.8	42	84	0	0	0	22.2
B-3	Friction grip nut M 16 IS 6623-8	42	84	0	0	0	8.7
B-4	Washer 'A' 17 IS 6649	45	90	0	0	0	2.8

FASTENING HARDWARE

	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (lb)
TOTALS	**44**	**80**	**111**	**627**

Tower Base Estimate Welding Details

Description (in mm)	Welding (ft)
2x4_4	7.8736
2x6_6	65.6248
Totals	73.4984

Cost of Steel :
$1100/ton

Cost of Fabrication:	
Cutting - (320 ft/day)	3 steelworkers @ $2.50/hour per steelworker, 8 hour workday
Drilling - (300 ea./day)	
Painting - (1.1 tons/day)	
Welding -(150 ft/day)	

	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (ton)	Welds (ft)
Totals	44	80	111	0.31	74
Labor Costs	$8.25	$16.00	$16.91		$29.60
Time (days)	0.14	0.27	0.28		0.49

Cost		Time Required for Fabrication (Days)
Material	**Labor**	
$341.00	$70.76	1.18
TOTAL Base Assembly Cost		
$411.76		

Tower Intermediate Steelparts Estimate

Part No.	Description (in mm)	Quantity	Quantity for Bridge	Cuts (ft)	Drills (ea.)	Paint (ft²)	Weight (lb)
I-1a	Angle 65/65/6 l = 1850	16	64	13.6	640	316.1	1499.8
I-1b	Rod ø 14 mm l = 2164	8	32	0	0	32.8	184.8
I-1c	Rod ø 14 mm l = 2536	8	32	0	0	38.4	216.6
I-2a	Rod ø 10 mm l = 3709	4	16	0	0	20.1	81.1
I-2b	Angle 60/40/6 l = 2505	8	32	6.3	128	162.2	773.2
I-3	Plate 380/296/6	4	16	15.5	224	38.7	182.0
I-4	Angle 80/80/8 l = 380	8	32	8.4	320	39.8	247.6
I-5	Plate 380/62/6	8	32	6.5	128	16.2	75.5
I-6	Plate 240/240/6	2	8	6.3	64	9.9	46.4
I-7	Friction grip bolt M 16 x 50 IS 3757-8.8	193	772	0	0	0	204.2
I-8	Friction grip nut M 16 IS 6623-8	193	772	0	0	0	80.0
I-9	Washer 'A' 17 IS 6649	193	772	0	0	0	23.8

FASTENING HARDWARE

	Cuts (ft)	Drills (ea.)	Paint (ft²)	Weight (lb)
TOTALS	**57**	**1504**	**674**	**3615**

Tower Intermediate Welding Details Estimate

Part No.	Description (in mm)	Welds (ft)
part I-1	2x6_6	80.3344
part I-2	2x6_6	30.0064
Totals		110.3408

Cost of Steel :
$1100/ton

Cost of Fabrication:	
Cutting - (320 ft/day)	3 steelworkers @ $2.50/hour per steelworker, 8 hour workday
Drilling - (300 ea./day)	
Painting - (1.1 tons/day)	
Welding -(150 ft/day)	

	Cuts (ft)	**Drills (ea.)**	**Paint (ft^2)**	**Weight (ton)**	**Welds (ft)**
Totals	57	1504	674	1.8	110
Labor Costs	$10.69	$300.80	$98.18		$44.00
Time (days)	0.18	5.01	1.64		0.68

Cost		**Time Required for Fabrication (Days)**
Material	**Labor**	
$1,980.00	$453.67	7.51
TOTAL Intermediate Assembly Cost		
$2,433.67		

Tower Top Element Steel Components Estimate

Part No.	Description (in mm)	Quantity	Quantity for Bridge	Cuts (ft)	Drills (ea.)	Paint (ft²)	Weight (lb)
T-1a	Angle 60/40/6 l = 1590	4	8	1.6	32	25.7	122.8
T-1b	Rod ø 10 mm l = 2536	2	4	0	0	3.4	13.8
T-2	Plate 420/360/6	4	8	0	120	22.9	107.9
T-3	Plate 310/65/6	8	16	0	64	6.4	32.1
T-4	Friction grip bolt M 16 x 50 IS 3757-8.8	60	120	0.0	0	0.0	31.7
T-5	Friction grip nut M 16 IS 6623-8	60	120	0.0	0	0.0	12.4
T-6	Washer 'A' 17 IS 6649	60	120	0.0	0	0.0	3.7
T-7	Angle 75/50/6 l = 240	2	4	1.0	16	2.5	11.5

FASTENING HARDWARE

	Cuts (ft)	Drills (ea.)	Paint (ft²)	Weight (lb)
TOTALS	**3**	**232**	**61**	**336**

Tower Top Element: Welding Details Estimate

Part No.	Description (in mm)	Welds (ft)
T-1	2x6_6	16.36
Total		16.36

Cost of Steel :	
$1100/ton	
Cost of Fabrication:	
Cutting - (320 ft/day)	3 steelworkers @ $2.50/hour per steelworker, 8 hour workday
Drilling - (300 ea./day)	
Painting - (1.1 tons/day)	
Welding -(150 ft/day)	

	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (ton)	Welds (ft)
Totals	3	232	61	0.17	16
Labor Costs	$0.48	$46.40	$9.27		$6.40
Time (days)	0.01	0.77	0.15		0.11

Cost		Time Required for Fabrication (Days)
Material	**Labor**	
$187.00	$62.55	1.04
TOTAL Top Assembly Cost		
$249.55		

Tower Saddle Element Steelparts Estimate

Part No.	Description (in mm)	Quantity	Quantity for Bridge	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (lb)
S-1a	Plate 170/65/6	8	16	3.4	32	3.8	16.6
S-1b	Plate 288/170/6	4	8	4.5	48	8.4	39.7
S-1c	Plate 388/202/8	4	8	10.2	0	13.5	76.7
S-1d	Plate 144/144/6	2	4	1.9	0	1.8	6.3
S-1e	Plate 388/144/6	2	4	1.9	8	2.4	23.0
S-1f	Plate 391/90/8	4	8	10.3	0	1.5	10.4
S-1g	Plate 430/170/12	2	4	5.6	16	6.3	44.6
S-1h	Plate 120/50/14	4	8	3.1	16	1.3	8.1
S-1i	Plate 122/100/10	8	16	6.4	16	4.2	28.6
S-2	Plate 170/120/20	2	4	2.2	16	2.3	25.7
S-3	Friction grip bolt M 20 x 120 IS 3757-8.8	9	18	0	0	0	15.1
S-4	Friction grip nut M 20 IS 6623-8	9	18	0	0	0	3.1
S-5	Washer 'A' 21 IS 6649	9	18	0	0	0	0.8
S-6	Cotter pin	9	18	0	0	0	0.1

FASTENING HARDWARE

	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (lb)
TOTALS	**49.53**	**152.00**	**45.46**	**298.80**

Tower Saddle Element Steelparts Estimate

Part No.	Description (in mm)	Welding (ft)
S-1-6	2x8_8	18.7392
S-1-6	2x6_6	32.2512
S-1-6	5	7.0368
S-1-6	3	8.9232
Total		66.9504

Cost of Steel :
$1100/ton

Cost of Fabrication:	
Cutting - (320 ft/day)	3 steelworkers @ $2.50/hour per steelworker, 8 hour workday
Drilling - (300 ea./day)	
Painting - (1.1 tons/day)	
Welding -(150 ft/day)	

	Cuts (ft)	**Drills (ea.)**	**Paint (ft^2)**	**Weight (ton)**	**Welds (ft)**
Totals	50	152	45	0.15	67
Labor Costs	$9.38	$30.40	$8.18		$26.80
Time (days)	0.16	0.51	0.14		0.45

Cost		**Time Required for Fabrication (Days)**
Material	**Labor**	
$165.00	$74.76	1.25
TOTAL Saddle Assembly Cost		
$239.76		

Cables General Material Calculations

Material	Description	QTY	Price/ Unit ($)	Transportation Costs ($)	Cost of Mat'ls ($)	Total Cost ($)	Donated ?	Actual Cost ($)
Main Cable (ft)	2 EA. (1-3/8")X297 ft 6x37 IWRC Drawn Galvanized EIPS	594	5.23	4487	3106.62	7593.62	Y	0
Spanning Cable (ft)	2 ea. 1" X 193 ft	386	2.96		1142.56	1142.56	Y	0
Fixiation and Handrail Cables	4 ea. (x2) 1/2" X 193 ft	772	1.02		787.44	787.44	Y	0
1-3/8" Forged Wire Rope Clips		28	6.95		194.60	194.60	Y	0
1" Forged Clips		20	4.00		80.00	80.00	Y	
1/2" Forged Clips		24	1.42		34.08	34.08	Y	0
1-3/8" Heavy Duty Thimble		4	12.93		51.72	51.72	Y	0
1" Heavy Duty Thimble		4	5.43		21.72	21.72	Y	0
1/2" Heavy Duty Thimble		8	0.78		6.24	6.24	Y	0
Total				4487	5424.98	**9911.98**		4566.6

Material Transportation Costs

Material	Unit Weight (lbs/ft)	Length (ft)	Weight/pcs	Pcs	Weight (Ibs)	Weight (tons)
Main Cable (ft)	3.5	594			2079	1.040
Spanning Cable (ft)	1.85	386			714.1	0.357
Fixation and Handrail Cables	0.46	772			355.12	0.178
1-3/8" forged wire rope clips			4.6	28	128.8	0.064
1" forged clips			2.6	20	52	0.026
1/2" forged clips			0.8	24	19.2	0.010
1-3/8" heavy duty thimble			12.95	4	51.8	0.026
1" heavy duty thimble			3.139	4	12.556	0.006
1/2" heavy duty thimble			0.51	8	4.08	0.002
				Total	3416.66	1.708

From Virginia to Panama City

Total (Dollars)	4130

From Panama City to Tole

(Assume 1 trip in total)	
Total (Dollars)	322

From Tole to Chichica

Material	Loading Capacity (Tons/ trip)	Trips QTY	Trips QTY /day	Unit Price (Dollars/ day)	Price (Dollars)
Main Cable (ft)	1	1.04	3	35	12.13
Spanning Cable (ft)	1	0.36	3	35	4.17
Fixiation and Handrail Cables	1	0.18	3	35	2.07
1-3/8" forged wire rope clips	1	0.06	3	35	0.75
1" forged clips	1	0.03	3	35	0.30
1/2" forged clips	1	0.01	3	35	0.11
1-3/8" heavy duty thimble	1	0.03	3	35	0.30
1" heavy duty thimble	1	0.01	3	35	0.07
1/2" heavy duty thimble	1	0.00	3	35	0.02
				Total (Dollars)	19.93
				Total (Dollars)	35

Total Transportation Cost (Dollars)	**4452**

Suspenders Steel Components Estimate

Part No.	Description (mm)	Quantity	Quantity for Bridge	Cuts (ft)	Drills (ea.)	Paint (ft²)	Weight (lb)
1a	Flat 40/10 l=254	1	90	_	_	_	224.64
1b	Rod Ø 12 of different lengths	_	226	8.90	_	116.91	493.175
1c	Flat 65/1 l=110	1	90	19.20	270	11.7	102.978
1d	Rod Ø 12 l=510	1	90	3.5433	_	17.1	90.081
2	Plate 80/70/3	2	180	41.346	720	18	48.816
3	Hexagonal Bolt M 16*90 IS 1363	1.05	95	_	_	_	35.211
4	Hexagonal Nut M 16 IS 1363	2.1	189	_	_	_	13.334
5	Hexagonal Screw M 10*25 IS 1363	4.2	378	_	_	_	20.835
6	Hexagonal Nut M 10 IS 1363	4.2	378	_	_	_	6.668

FASTENING HARDWARE

	Cuts (ft)	Drills (ea.)	Paint (ft²)	Weight (lb)
TOTALS	**73**	**990**	**164**	**1036**

Suspenders Welding Details Estimate

Part No.	Description (mm)	Quantity	Quantity for Bridge	Welds (ft)
1b	8 (3/8") fillet	2	452	45.2
1c	6 (1/4") fillet	4	360	44.496
			Total	**89.696**

Cost of Steel :
$1100/ton

Cost of Fabrication:	
Cutting - (320 ft/day)	3 steelworkers @ $2.50/hour per steelworker, 8 hour workday
Drilling - (300 ea./day)	
Painting - (1.1 tons/day)	
Welding -(150 ft/day)	

	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (ton)	Welds (ft)	Loops (loop)
Totals	73	990	164	0.00	89.696	226
Labor Costs	$13.68	$198.00	$0.00	-	$37.31	$188.33
Time (days)	0.23	3.30	0.00	-	0.60	3.139

Cost		**Time Required for Fabrication (Days)**
Material	**Labor**	
$569.66	$465.58	8
TOTAL Suspenders Assembly Cost		
$1,035.24		

Walkway Components Estimate

Part No.	Description (mm)	Quantity	Quantity for Bridge	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (lb)
1-a	Angle 50/50/6 l = 1520	8	16	2.6	96	49.2	239.1
1-b	Flat 65/6 l = 156	4	8	1.7	24	1.7	7.9
1-c	Flat 65/6 l = 300	4	8	0.0	0	0.0	0.0
1-d	Flat 65/6 l = 100	4	8	1.7	8	11.8	5.2
2	Flat 40/6 l = 1720	4	8	1.0	24	4.5	57.1
3	Rod ø 16 l = 437	8	16	0	0	8.0	22.5
4	Flat 40/6 l = 88	4	8	0.2	8	0.5	2.8
5	Hexgonal bolt M 16 x 50 IS 1363	2	4	0	0	3.1	0.9
6	Hexagonal Nut M 16 IS 1363	4	8	0	0	8.6	0.6
7	Hexgonal bolt M 12 x 70 IS 1363	4	8	0	0	4	1.3
9	Hexagonal Nut M 12 IS 1363	42	84	0	0	0	3.3
9	Plain Washer ø 13	42	84	0	0	0	1.5
10	Wire Nail ø 5 l = 100	45	90	0	0	0	3.0
11	Binding Wire ø 1.6	n/a	9 m	0	0	0	0.0

FASTENING HARDWARE

	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (lb)
TOTALS	**9**	**160**	**95**	**361**

Walkway Miscellaneous and Welding Details Estimate

Misc.

Description (in mm)	Quantity for Bridge	Cuts (ft)	Drills (ea.)
Wire Mesh Netting (4x12 ft)	31	–	–
Longitudinal planks l = 239 cm Thickness = 5 cm	157.5	1234.674	185.2011
Nailing Strip 120/18/5cm	45	177.12	26.568
TOTAL		1411.794	211.7691

Welding Details:

Description (mm)	Welds (ft)
4 mm fillet	11.182

	Cuts (ft)	Drills (ea.)	Paint (ft^2)	Weight (tons)	Welds (ft)
TOTALS	**8.95**	**160**	**94.80**	**0.18**	**11.18**
Costs $	**1.68**	**32**		**198.85**	**4.47**

Cost		Time Required for Fabrication (Days)
Material	**Labor**	
$198.00	$47.91	0.80
TOTAL Walkway Assembly Cost		
$245.91		

Material and Equipment Within Panama

Supplier	Location of Supplier	Supplier Information	
Cochez	Santiago, America Way (Vía Interamericana), Balboa Ave Panama	http://www.cochezycia.com 775-7864	
Material/Description		***Cost of Material***	***Unit of Material***
General Purpose Portland Cement		8.9	per 42.5kg bag
Gravel		15.95	per 20cft
Sand		13.90	per 1 cubic m
Masonry Block		25.00	per cubic yard
Rebar, #3		5.00	#3 40' section
Plywood, 3/4"x4'x8'		9.50	per sheet
Southern Pine, 2"x6"x14'		2.00	per board
Tie Wire		30	per 100 lb
16 Penny Nails		2.00	per pound
Wire Mesh Fencing, 4'x12' Section		37.00	per roll
Metal Surface Paint		27.95	per gallon
Transport from Santiago to Tole		90.00	per trip, 2 trips/day

Supplier	Location	Supplier Information	
Jessica Rudder	Chichica	Peace Corp Volunteer	
Objective		***Cost/Day***	***Trips/Day***
Transportation from Tole to Chichica		$45.00	2

Supplier	Location	Supplier Information	
Hopsa	Santiago/David, Panama	Airco Equipment Sales 774-4456 http://www.hopsa.com	
Material/Description		***Cost of Material***	***Unit of Material***
4'x8' corrugated plastic sheets		6.20	per sheet
2 in outlet water pump		528.58	each

Supplier	Location	Supplier Information	
Medina Tool	David, Panama	medinatoolrental@yahoo.com	
Material/Description		***Cost of Material***	***Unit of Material***
7kw, gas powered Generator		225.00	per week
2 in outlet, gas powered water pump		30.00	per day
		150.00	per week
Jackhammer/Chipper 90 lb with an Air Compressor		125.00	per day
Electric Drill		65.00	per week
		can also get drill bits	
Transport		100.00	per trip from David to tole

Material and Equipment Outside Panama

Supplier		Supplier Website
Mays Trail Equipment		**www.maystrailequipment.com**
Lowe's		**http://www.lowes.com/**
Material/Description	***Cost of Material***	***Unit of Material***
Pionjar jackhammer/vibrator	231.63	per month
Task Force 16 Oz. Smooth Hammer	3.98	each
Kobalt 25' Metric and	10.98	each
Kobalt 12" Finishing	15.98	each
Truper 47" Fiberglass Long Handle Round-Point Shovel	9.98	each
True Temper 4 Cu. Ft.	34.97	each
Chain Saw	109	each
Oregon 2-Pack 14" Replacement Saw Chain	19.96	each
Stanley 15" Hand Saw	13.98	each
Poulan Pro Quick Start Oil Kit	5.68	each
Encore Plastics 5-Gallon Gray Pro Logo Pail	2.78	each
Fi-Shock High-Tensile Wire Cutters	24.12	each
Blue Hawk 3" Deck Screws	2.97	each

Northern Tool & Equipment	www.northerntool.com
High Test Chains	
Pulley Blocks (5 ton)	
Pulley Machine (3.2 ton)	
Come Along (2 ton)	
Rope (100ft)	
Hooks	
Pulley Machine (1760 lb)	
Pulley Blocks (4 ton)	

Heco Slings Corporation	www.hecoslings.com
Wire Rope, 36 mm	
Wire Rope, 26 mm	
Wire Rope, 13 mm	
Wire Clips	
Thimbles	